MUCORALES OF INDIA

By

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

First Printed, October 1968

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Printed in India by the United India Press, Link House, Bahadur Shah Zafar Marg, New Delhi, and Published by T S. Pruthi, Under-Secretary, for the Indian Council of Agricultural Research, New Delhi.

PREFACE

Numerous papers have been published on the fungi of India, but the literature is so dispersed that it becomes difficult to collect the requisite information easily Dr M S Randhawa, the former Vice-President of the Indian Council of Agricultural Research, realized this difficulty of the Indian botanists and eventually initiated a programme for publication of monographs on certain groups of fungi as well as on the diseases of important trees and crops For this act, the Indian botanists will remain ever grateful to him.

Even though in India the work on fungi has mostly been confined to pathogenic forms, the Mucorales have not been completely neglected This order has been studied while different fungi were isolated from different types of substrates A large number of them are saprophytic, but some of them have been found to cause diseases of plants or other fungi. The structure, reproduction, physiology and taxonomy of both the groups have been dealt with in this monograph Nineteen genera and 67 species have been described. All the types reported from this country have been described, even though the original investigators mostly gave the names of the organisms and the source from which they obtained them

The author has made extensive use of all the published literature on this order and wishes to express his grateful thanks to all those whose work has been consulted. They are too many to be named individually He is also thankful to Dr S B Saksena, Head of the Department of Botany, Saugar University, Km C R Rugmini, Research Student, now at the Botany Department, Banaras Hindu University, and Dr B S Raizada, Research Scholar, Botany Department, Allahabad University, for permitting the use of some unpublished results incorporated in their theses Thanks are also due to Dr C W. Hesseltine, Incharge, Culture Collection Unit, U S Department of Agriculture, Peoria, Illinois, for very promptly sending his papers without which the completion of the present work would have been delayed Lastly, it is the most pleasant duty to thank Dr K S Bilgrami of the department of Botany, University of Allahabad, for his ungrudging help in completion of this monograph.

The help and suggestions given by Dr P. Kachroo, and Mr S N. Tata, of the Indian Council of Agricultural Research, in the finalization of the manuscript for the press are gratefully acknowledged.

R.N. TANDON

CONTENTS

I GENERAL ACCOUNT

Historical introduction

Knowledge of the order Mucorales, commonly called 'black moulds', dates back to the middle of seventeenth century, when Roberts Hooke described a black mould which may well have been *Rhizopus nigricans* A few years later a definitely known member of the Mucorales, viz, *Pilobolus*, was described by John Ray (1688), but this genus was properly created by Tode in 1790 Though the starting of nomenclature of this order began with Fries, he first placed it with puff balls (Gasteromycetes) Subsequently he modified his older views, and in the third volume of his *Systema Mycologicum* he kept them under the Hyphomycetes Even at that stage the position was incorrect as it included a number of genera which did not belong even to Phycomycetes

Sixteen species of *Mucor* and one of *Thamnidium* were described by de Schweinitz in 1834

In spite of sufficient amount of work, this group was not regarded as a separate order till 1870 A clear understanding of this order started with the publication of three papers by van Tieghem and van Tieghem and le Monnier They defined the family Mucoraceae in 1873, and established several genera which are valid till today Complete descriptions with spore measurements and full illustrations were published, van Tieghem also studied the growth of these organisms by culture technique, and considered that they all belonged to a single family Mucoraceae Berlese and de Toni (1888) also treated Mucorales in the same manner Brefeld (1881) was the first person to undertake cultural studies of these types and give some beautiful illustrations He was responsible for creating the subclass Zygomycetes, but Hesseltine (1955) rightly mentioned that 'his descriptions, however, leave much to be desired'

Schroter (1886) created a suborder to include *Mucors*, but Fischer (1892) was responsible for giving a modern concept to these types His order Mucorineae embodied five families Subsequently, Zycha (1935) closely followed this system, and all have recognized the group as an order which is divided into varying number of families The uncertainty about classification is due to the absence of general agreement about the phylogenetic relationships within the group Lendner (1908) and Hagem (1908, 1910) added to our knowledge of this order Fitzpatrick (1930) gave the first detailed account in English He divided it into seven families, but a few years later Zycha (1935) recognized six families only Naumov (1939) recognized eight families Linder (1943) established the family Kickxellaceae Christenbury (1940) studied the Mucorales of South United States, but he followed Zycha (1935) and recognized six families only Bessey (1950) recognized eight families which are only slightly different from those of Fitzpatrick Hesseltine (1953) slightly modified Martin's (1946) suggestions and recognized nine families These are discussed under classification

In India, in general, very little work has been done on this group, and most of it is of indirect nature Various members of this order have been reported while studying the fungous flora of the particular region or of different types of soils, or on dung of different animals Mostly only the name of the organism has been reported and no detailed study has been undertaken Thus, our knowledge of Indian flora is very fragmentary and incomplete However, in recent years some attempts have been made to study the order in greater detail

The first report of a definite member of this order from India was made by Currey in 1873 He noticed *Choanephora infundibulifera* on flowers of *Hibiscus rosa-sinensis* at Calcutta, and named it *C cunninghamiana* Later Cunningham (1895) found that *C simsoni* was parasitic on living flowers of *Zinnia elegans* Butler (1915) reported *Cunninghamella elegans* from soils of Pusa In the same year, Hutchinson and Ram Ayyer (1915) isolated *Rhizopus combodia* from fermenting rice from Darjeeling (West Bengal) and Khasi Hills (Assam) Dastur (1920) reported *Choanephora cucurbitarum* on chillies at Pusa He also recorded *Rhizopus artocarpi* at Banaras, a species earlier reported by Mitra (1921) from Andamans Ajrekar and Rajulu (1931) described the Mucorales of Bombay city They reported eight species but did not give detailed description of any of them Mahju (1933) studied the fungi on dungs of rabbit, *sambhar*, horse, goat, buffalo and sheep He collected 29 species, but only four of them—*Pilobolus longipes*, *P minutus*, *P crystallinus* and *Mucor mucedo*—belonged to this order Ginai (1936) studied the flora on dungs of cow, *nilghai*, camel, zebra and donkey He collected 48 species which included nine members of Mucorales—*Mucor mucedo*, *M griseosporus*, *Syncephalis sphaerica*, *Syncephalis* sp , *Pilobolus crystallinus*, *P longipes*, *P nanus*, *P. kleinii* and *Pilobolus* sp

Thakur and Norris (1928) studied soil fungi from south India and recorded *Mucor glomerula*, *M plumbeus*, *M. praini*, *M. racemosus* and *Rhizopus nigricans* Chaudhuri and Sachar (1934) studied the fungi of Punjab soils, and isolated 32 species, but only four of them—*Rhizopus nigricans*, *R. arrhizus*, *Cunninghamella verticillata* and *Mucor circinelloides*—belonged to Mucorales Galloway (1936) studied the soil fungi from Pusa and some hill districts of northern India, and listed four members of this order, i e , *Rhizopus arrhizus*, *Cunninghamella echinulata*, *Syncephalastrum* sp and *Mucor* sp He particularly stressed the paucity of Mucorales in the tropical region of India

Nineteen fungi were observed by Hukum Chand (1937) in the soils of Lahore, but only four belonged to this order, i e , *Pilobolus nodosus*, *Mucor botryoides*, *Choanephora* sp and *Cunninghamella echinulata* Ghatak and Roy (1939) as well as Roy (1948) studied the soil fungi of paddy fields, but they isolated only *Mucor racemosus*, *M. hiemalis*, *Rhizopus nigricans* and *Cunninghamella verticillata* Besides these the former authors had also obtained an unidentified species of *Rhizopus* Prakash and Saksena, R K (1952) studied the fungi of Allahabad soils with special reference to their decomposing action on paddy and *bajra* They reported *Absidia heterospora*, *Cunninghamella bertholletiae*, *C echinulata* and *Syncephalastrum racemosum*

Saksena, S B and his students have studied the fungal flora of forests and grasslands of Saugar They have recorded seven members of Mucorales from the soils of

Saugar, which included a new genus Murty (1952) studied the soils of Saugar with special reference to edaphic factors and reported *Rhizopus nigricans Absidia* sp *Mucor* sp and *Cunninghamella verticillata* Shetye (1954) studied the soil fungi from *Tectona* and *Diospyros* forests He reported the presence of *Absidia repens Cunninghamella bertholletiae, Mucor racemosus* and *Rhizopus nigricans* Rugmini (1956) studied the Mucorales of Saugar and described a number of types not reported before

Saha (1945) studied the rot of certain Indian fruits and reported the presence of *Mucor racemosus, M silvaticus* and *Absidia blakesleana* Raizada (1957) recently undertook physiological studies of some members of this order Subramanian (1952) described *Rhizopus oryzae* from tobacco field soils of Madras State Sinha (1940) described *Choanephora cucurbitarum* and *C trispora* on *Colocasia antiquorum* and *C cucurbitarum* on chillies He considers that *Blakeslea trispora* should be called *Choanephora trispora*

Bhattacharya and Baruah (1953) reported a number of fungi from Assam and they included many members of Mucorales Rajan *et al* (1952) reported *Rhizopus stolonifer* (*R nigricans*) from atmosphere at Kanpur Mitter and Tandon (1930) observed *Rhizopus artocarpi* on *Artocarpus integrifolia* and *Rhizopus* sp on *Ficus carica* at Allahabad They also reported (1937) *Choanephora cucurbitarum* on *Hibiscus esculentus, C infundibulifera* on *H rosa sinensis* and *C simsoni* on cultivated species of *Zinnia* from the same region Ramakrishnan (1953) observed *Syncephalis cornu* as a parasite on the hyphae of *Cunninghamella echinulata*, and *S reflexa* on the hyphae of *C bertholletiae*

According to Naumov (1939), who has subdivided many of the older genera, the Mucorales comprise about 38 genera and 340 species and subspecies, excluding Endogonaceae, including the latter, the order comprises 44 genera and about 370 species The list of Mucorales prepared by Bisby *et al* (1933) indicates that 40 per cent of the Phycomycetes which occur in India appear in Europe also They are mostly saprophytic on plant and animal tissues, although a few species are pathogenic and cause decay of fruits and vegetables *Choanephora cucurbitarum* is widely parasitic on the flowers and fruits of squash as well as on a number of other plants, including cowpea *Rhizopus artocarpi* causes rot of young fruits of *Artocarpus integrifolia* and often kills them *Absidia corymbifera* is associated with human bronchomycoses and *A cornealis* with lesions of cornea *Mortierella niveo-velutina* causes lesions on skin *Mucor baineri, M simplex, Piptocephalis fresiniana, Dispira cornuta* and various species of *Syncephalis* are parasitic on other Mucorales Dobbs (1942) reported that a species of *Piptocephalis* is parasitic on *Penicillium notatum, P glabrum, P roqueforti, Aspergillus niger, Mucor mucedo* and *M hiemalis*

Some members of this order are used for industrial purposes A number of them can cause alcoholic fermentation, but *Rhizopus oryzae* and *Mucor javanicus* are often used for this purpose, while *Rhizopus arrhizus, R oryzae, R japonicus, R nodosus, R stolonifer* and *Mucor rouxii* can synthesize lactic acid Lockwood *et al* (1936) reported that glucose was the best sugar for producing lactic acid by *R oryzae*

II. STRUCTURE

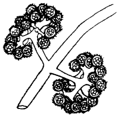
In general, the Mucorales possess an extensive and richly branched mycelia at first coenocytic but later commonly septate They can readily grow on ordinary culture media upon which asexual fructifications are commonly produced. Senescent hyphae, or those produced in the presence of high concentration of sugar, may get segmented and bud in yeast-like manner. Species of *Rhizopus* and *Absidia* produce runner-like hyphae called stolons

The cell wall is reported by von Wettstein (1921) to lack cellulose, and to contain chitin and pectose compounds, but Mangin (1899) reported true cellulose in young sporangia of some species Hopkins (1929) found both cellulose and chitin in *Mucor rouxianus* (Calmette) Wehmer It must, however, be noted that Nabel (1929) could not find cellulose in this species or in any other member of this order It is thus clear that a more detailed investigation is necessary in order to understand the real nature of the cell wall Inside the cell wall there is a cytoplasmic layer with numerous nuclei, vacuoles and the usual food-storage products

Asexual reproduction is typically by formation of non-motile encysted spores (aplanospores) in sporangia which are mostly terminal on hyphae. These sporangia are formed on erect sporangiophores which are usually unbranched, except in some cases such as verticillately branched sporangiophores of *Thamnidium elegans* (Fig. 1). The dichotomously branched ones are of *Blakeslea trispora* (Fig. 2), *Choanephora manshurica* and *Sporodinia grandis* (Fig 3), and circinately corymbose ones of *Circinella minor* (Fig. 4)

A swelling develops at the tip of the sporangiophore or its branches, and this is then cut off by a septum (Fig 5) to delimit the sporangium This septum may remain plane (Mortierellaceae, Fig 6) or develop a globular, cylindric or pyriform dome-like structure (Fig. 7A) known as columella in Mucoraceae. In general, the sporangia are formed in the same manner as in the Saprolegniales or Peronosporales. The multinucleate contents of the sporangium are divided by cleavage planes into naked, at first polyhedral, cells containing one or more nuclei each These then round up, encyst and escape by the rupture or dissolution of the sporangial wall (Fig. 7B) They germinate by means of a short germ tube. There are three main types of variations in the development of spores, as fallows:

1. In *Pilobolus crystallinus* and *P. oedipus* the sporangial content is usually cleaved into uninucleate portions along the lines of the vacuoles and they use up all the protoplast. The portions round up at a later stage Each nucleus divides a number of times and ultimately each develops a membrane.
2. Multinucleate masses are formed as a result of cleavage. These subsequently round up and are invested with a membrane. This type is illustrated by *Rhizopus nigricans, Phycomyces nitens, Sporodinia grandis. Circinella conica* and *C. minor.*



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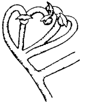

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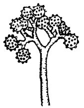

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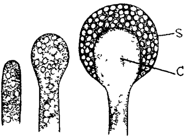

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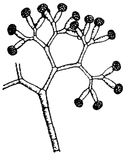

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FIG 1 *Thamnidium elegans* Link. Sporangiola (After Brefeld, 1881)

FIG 2 *Blakeslea trispora* Thaxter Groups of globose heads denuded of sporangiola (After Thaxter, 1914).

FIG. 3 *Sporodinia grandis* Link Sporangiophores and sporangia (After Lendner, 1908)

FIG 4. *Circinella minor* Lendner Opened sporangia with columella (After Lendner, 1908)

FIG 5 *Mucor* sp Development of sporangium at the end of a sporangiophore S, spores, C, columella (After Coulter).

FIG 6 *Mortierella rostafinskii* Bref A sporangium (After Brefeld)

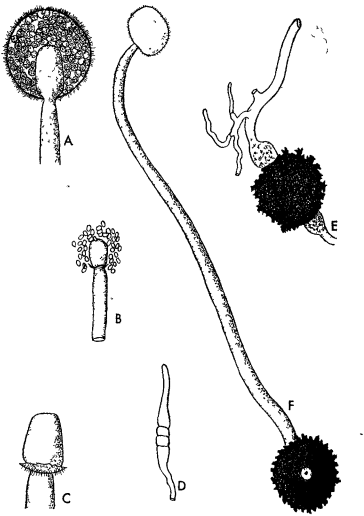
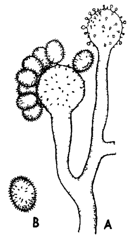


FIG 7 *Mucor mucedo* Fres A, a mature sporangium before escape of spores, B, escape of spores upon dissolution of sporangial wall, C, columella after escape of spores, D, sexual reproduction in early stage, thin-walled gametangia in contact, E, mature zygospore, F, germinating zygospore (After Brefeld)



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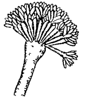

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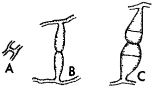

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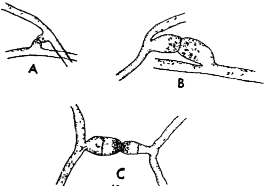

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FIG 8 *Cunninghamella echinulata* Thaxter **A**, echinulate conidia covering capitate termination of conidiophores, **B**, a single conidium (After Thaxter, 1891)

FIG 9 *Syncephalis* sp Enlarged apex of fertile hyphae from which radiate branches terminated by clusters of tubular sporangia (After Thaxter, 1987)

FIG 10 *Chaetocladium brefeldii* van Tiegh Germinating conidium (After Brefeld 1872)

FIG 11 *Rhizopus nigricans* Ehrenb A, adjacent hyphae uniting by young progametangia B progametangia, C, gametangia and suspensors (After Fitzpatrick)

FIG 12 *Mucor hiemalis* Wehm A, contact of progametangia, B, one gametangium is larger than the other, C, contents from the — gametangium are passing in the + gametangium (After Williamson)

3 The tip of sporangiophore enlarges into capitate structure in *Cunninghamella echinulata* (Fig. 8A) and *C berthollettae*. Small projections called sterigmata are developed from these, and small globular structures develop at the tip of the sterigmata They receive the protoplasm along with three to eight nuclei and are ultimately converted into spores (Fig. 8B)

There are some modifications in the three main methods described above. In *Syncephalis* and *Syncephalastrum* long tube-like structures (sporangia) may be developed at the tip of the sterigmata, and may project in all the directions from the globular head (Fig 9) Each sporangium is multinucleate and has uni- or multinucleate spores, arranged in linear series The sterigmate sporangia of *Blakeslea trispora* are elongate, spherical and have three spores or rarely one only, but in other respects they show similar development The sporangium of *Chaetocladium jonesi* and *C. brefeldii* (Fig 10) have a single spore *Mycotypha microspora* develops one-spored sporangia which are abstricted from the tip of the sterigmata. Schostakowitsch (1896) reported that in *Mucor proliferus* the columella forms a new sporangium by proliferation, reminding one of the condition in *Saprolegnia*. The sporangium of *Pilobolus* is peculiarly modified. The apical wall of the sporangium is greatly thickened. A sub-sporangial vesicle is developed below the sporangium, and this may be two or three times the diameter of the flattened sporangium. The tip of the sporangiophore is sensitive to light, and due to curvature of its lower part the sporangium is directed toward the source of light The vesicle enlarges and the turgor increases, due to which the apex ruptures and the sporangium is blown off

Swingle (1903) has shown that all the protoplasm in the sporangium is used up in the formation of spores Like the Peronosporales, Mucorales also show a gradual transition from sporangium to conidium

The endogenous spores are no longer evident in higher forms In intermediate conditions the sporangium exists as a deciduous, few-spored body to which the name sporangiolum has been applied Although it is evident that conidium is the homologue of sporangium and might have been derived from it through sporangiolum, at least in some cases, the application of the three terms to the three types of structures can be accomplished without appreciable ambiguity because few border-line confusions are encountered in this group. The transition from sporangium to sporangiolum can be demonstrated in *Blakeslea*, while the origin of conidium from monospored sporangiolum is evident in *Chaetocladium* and *Haplosporangium* Most mycologists consider that the so-called one-celled 'conidium' should be interpreted as sporangium and not conidium The presence of the wall associated with the spores and the method of spore germination lend sufficient support to their views

Sexual process of various members of Mucorales has been studied by many investigators In *Mucor*, at a point where two hyphae come in contact a swelling occurs on each hypha, pushing them apart Thus, pairs of lateral branches, called progametangia (Fig 11A, B), are developed. In heterothallic types the hyphae must come from plants of opposite sex The two swellings flatten against one another and become enlarged, each tapers towards the hyphae from which it arises. Cross walls soon appear and cut off two gametangia (Fig 11C) The remainder of progametangium is called

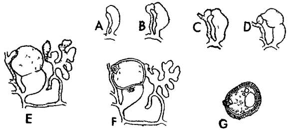

FIG 13 *A*. *Dicranophora fulva* Schroet A–G, successive stages in sexual reproduction showing difference in size of gametangia (After Dobb) Bottom,

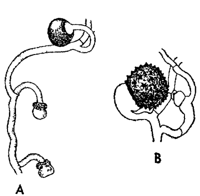

FIG 13 *B*. *Zygorhynchus macrosporus* Ling A, sporangiophores and sporangia, B, anisogamous formation of zygospores (After Ling-Young)

suspensor Each gametangium has a dense mass of cytoplasm with numerous nuclei The double wall separating the gametangia dissolves from the centre and ultimately the whole intervening wall disappears The products of the two gametangia get mixed and fill the cavities of gametangia. The walls of the original gametangia may persist in young zygospore, but soon distinct dark plates or pyramids are laid within the original wall, and two-to three-layered wall of the zygospore is laid inside the plates. The original gametangial wall is ultimately broken into small pieces and finally the exterior is covered with dark plates which appear as short spines Ling-Young (1930) reported that gametangia and suspensor of vigorous (female) strains of many heterothallic species are longer, and in *Mucor hiemalis* even the contents of the male gametangium pass to the female gametangium which then becomes closed Thus, in this species the zygospore is formed only from the female gametangium (Fig 12A–C) In some Mucorales the gametangia and suspensor are unequal In *Dicranophora* (Fig 13 *A*) one of the gametangium is many times longer than the other, while in *Zygorhynchus* (Fig. 13*B*) there is marked difference between the two.

In some cases (viz , *Phycomyces*, *Pilobolus*, *Mortierella* and *Piptocephalis*) the limiting hyphae may become attached by finger-like process, or they may once or twice coil around each other They may then grow parallel and remain in contact, but after some time they curve away and bend Ultimately they appear like pairs of tongs; and only the tips remain in contact (Fig 14) In *Piptocephalis* and *Endogone* external zygospore is developed through budding from structures representing the two united gametangia (Figs. 15–19)

Generally, the zygospore remains naked but in *Phycomyces nitens* (Fig. 20) it is loosely surrounded with stiff, black, more or less dichotomously branched processes arising from suspensors The protective structures of *Absidia glauca* are curved and hooked (Fig. 21). Mostly, the protective structures of these species arise from the female gametangium A many-layered, dense hyphal mass is closely appressed to the zygospore of *Mortierella* (Fig. 22 A–C)

Under natural conditions the zygospores were known to appear commonly in some cases, while in others they were either not developed or appeared erratically. Earlier investigators felt that the production in latter cases was correlated with environment and used various methods to induce their development, but none of them was dependable Even known zygosporic cultures sometimes failed to produce them. The sudden appearance of zygospores under widely different conditions, both environmental and nutritive, could not be easily explained A proper explanation was given by Blakeslee (1904), who studied the zygospore formation in *Mucor mucedo* He noticed distinct sexuality in Mucorales. He showed that the hyphal branches from the mycelium arising from a single sporangiophore of some species interact to form zygospores and termed such types 'homothallic' In other species the zygospores did not mature unless the interacting hyphae were from two sporangiophores of different potentialities. He termed such species 'heterothallic' One of these thalli is functionally female (+) and the other functionally male (—) Sometimes the two strains + and — may be distinguished on account of slight difference in luxuriance of their growth, although there may be no other morphological difference. Various homothallic and heterothallic

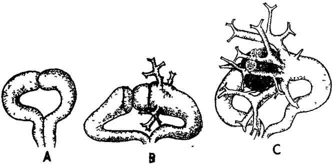

FIG 14 *Phycomyces microsporus* van Tiegh A–C, stages in the formation of zygospore (After Christenberry)

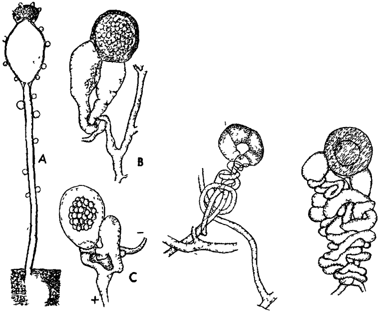

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FIG 15 *Pilobolus kleinii* van Tiegh A, B, sporangium and zygospore (After Zopf), C, *Pilobolus crystallinus* Tode. Heterothallic formation of zygospore (After Krafczyk)

FIG. 16 *Choanephora conjuncta* Couch Young stage of sexual reproduction (After Couch).

FIG 17 *Choanephora conjuncta* Couch Sexual reproduction with mature zygospore (After Couch)

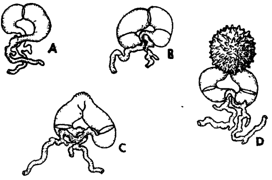


FIG. 18. *Piptocephalis fresiniana* de Bary A–D, stages in zygospore formation.

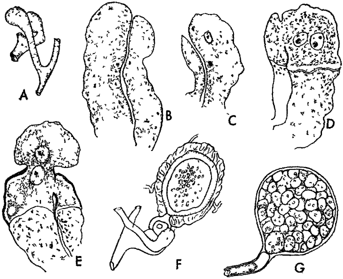
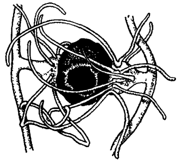
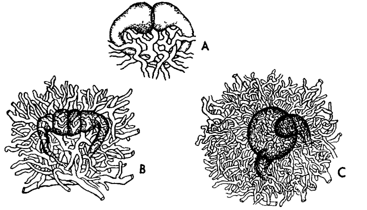


FIG. 19. *Endogone lactiflua* Berk. A, young gametangium, B, gametangia in longitudinal section; C, gametangia in longitudinal section showing one privileged nucleus in right gametangium, the others receding basally, D, gametangia set off by septa and male nucleus entered into female nucleus; E, zygospores budding out from top of female gametangium, F, practically mature zygospore, G, *Endogone pisiformis* Link Mature sporangium (After Bucholtz)

20



21



22

FIG 20 *Phycomyces nitens* Kunze Mature zygospore with rigid and dichotomously branched outgrowths from the suspensor (After van Tiegh and le Monn , 1873)

FIG 21 *Absidia glauca* Hagem Mature zygospore covered with protective structures (After Lendner)

FIG 22 *Mortierella rostafinskii* Bref A–C, stages in production of zygospore covered with hyphal clusters

species have been differentiated on the basis of such studies *Sporodinia grandis*, *Absidia spinosa*, *Dicranophora fulva* and *Rhizopus sexualis* are some of the homothallic forms, while *Absidia coerulea*, *Blakeslea trispora*, *Choanephora cucurbitarum*, *Mucor mucedo*, *M. hiemalis*, *Phycomyces nitens* and *Rhizopus nigricans* are heterothallic. This clearly shows that some species of a genus may be homothallic while the others may be heterothallic.

Blakeslee (1920) and others established that sexual differences show different degrees of intensity. The mode of union of the gametangia may be dependent on the intensity of sexual characters. Thus, a strongly male plant will readily conjugate with plants of all degrees of femaleness and vice versa, but weakly male plants will not conjugate with weakly female plants.

Satina and Blakeslee (1926) made chemical tests on two different strains of several species and found different reactions. They considered that the method could be used for differentiating the particular sex of Mucorales

Blakeslee also noticed imperfect hybridization between opposite strains of different heterothallic species as well as between both + and — strains of heterothallic species on the one hand and homothallic species on the other. The power of hybridization between different species of Mucorales has made it possible to place the + and — strains of various types in their suitable positions. Burgeff (1925) extensively used this method for correlating sexes in various genera and species of Mucorales. He even succeeded in producing the first hybrid between two fungi *Phycomyces blakesleeanus* and *P. nitens*.

Ling-Young (1930) showed that if two colonies of the same sex of *Phycomyces nitens* are grown in culture media which may be poor in nutrient, they cease to grow when they reach a distance 1–1.5 cm apart; but if the hyphae are of opposite sex they intermingle and soon form zygospores. This resembles the condition observed by Vandendries and Brodie (1933) in some Basidiomycetes.

Cytological features associated with fertilization have been studied in some species of Mucorales, but due to the small size of their nuclei and the presence of large amount of oil in zygospores, the results recorded by different investigators are incomplete and even contradictory. It is generally agreed that the young gametangia are multi-nucleate, and many investigators describe the disintegration of supernumerary nuclei. Lendner (1908) suggested single nuclear fusion and reported that in *Sporodinia grandis* all except one pair of nuclei in the united gametangia disorganize and the zygote was developed by the fusion of that single pair. Keene (1919) worked on *Phycomyces nitens* and mentioned that the nuclei were reduced to six or eight pairs. Dangeard (1906) and Moreau (1913) considered that the majority of the nuclei (and not one or a few pairs) unite. This was confirmed by Ling-Young (1930). Cutter (1942) seems to confirm the results of Dangeard, Moreau and Ling-Young. He made elaborate studies on the nuclear behaviour of some members of Mucorales and stated that the mucoraceous nucleus is very small and presents difficulties in the study of divisions through the usual cytological technique. He grouped the nuclear pattern of Mucorales into four types, viz., (1) the *Mucor* type, (2) the *Rhizopus* type, (3) the *Phycomyces* type, and (4) the *Sporodinia* type.

In the *Mucor* type all functional zygospore nuclei undergo karyogamy followed by immediate reduction prior to the onset of dormancy in the zygospore. Segregation of sex is complete in heterothallic species at meiosis. There is no nuclear fusion or reduction in azygous variety, i.e., *Zygorhynchus vuilleminii* var *agamous*. Cutter (1942) feels that the *Rhizopus* pattern might have originated from the *Mucor* pattern by restriction of karyogamy to certain favoured nuclei and deferment of the meiotic process until the time of germination. This condition is carried further in the *Phycomyces* type, where association, but not fusion, of nuclei occurs early in the formation of the zygote, the fusion being delayed until the time of germination, where it is still restricted to favoured nuclei. This condition appears more specialized than that of the *Rhizopus* type because all the fusion nuclei do not undergo meiosis in the first generation and certain nuclei possibly persist throughout the life cycle without undergoing karyogamy. The persistence of unfused nuclei correlated with only partial meiosis and possibly degeneration of fusion nuclei may indicate the origin of the *Sporodinia* type in which karyogamy is apparently obsolete and unfused nuclei are regularly present throughout the life cycle. These specializations in the nuclear behaviour can be correlated with a general increase in the size and complexity of the thallus, as well as with an increasing tendency for the reproductive structures to be borne on specialized zygospore hyphae or zygophores rather than on an apparently undifferentiated vegetative mycelium.

While studying the nuclear behaviour, Cutter (1942) paid special attention to the nature of the chondriome. He observed delicate, long, thread-like mitrochondria in the developing sporangia and the hyphal tips of the mycelium of *Mucor genevensis* in the regions of active cytoplasmic movements. As the cytoplasmic activity ceased, these mitrochondria were seen only in granular form. According to him the oil plastids were formed by the coalescence of these granules.

After a period of rest the zygospore may germinate by the formation of small germ tube which terminates into a germ sporangium. Blakeslee observed that with reference to + and — characters, there are three distinct types of germination

(a) All the spores from the germ sporangium of *Sporodinia grandis* are purely homothallic

(b) The spores from the single germ sporangium of *Mucor mucedo* are either all + or all —, i.e., the germ sporangium produces unisexual spores

(c) In *Phycomyces nitens* some spores are unisexual while others are bisexual

It has been observed that under some environmental conditions unmated gametangia become thick-walled and may be designated as azygospores. Some persons have called them chlamydospores, but it may be pointed out that in many Mucorales the chlamydospores may be produced without any connection with the gametangia

III. PHYSIOLOGICAL STUDIES

In spite of numerous isolations of Mucorales from our country, very little physiological work has been undertaken. Interesting information about the effect of various external factors on the growth and sporulation of these organisms has been collected in various parts of the world. A short account of these is included here so that one may be able to understand the peculiar behaviour of various members of this order. It will also indicate the need for detailed physiological studies of these fungi in India.

Like other plants, the fungi also need the various essential elements which include carbon, nitrogen, oxygen, hydrogen, phosphorus, sulphur, potassium and various trace elements It has been shown that absence of any of the above substances greatly influences the growth and sporulation of fungi, and that fungi are very selective in their choice of different substances. They obtain the elements from various sources which may differ considerably with the organisms; even closely related forms may obtain their supply from different sources. It is, therefore, essential to know the exact requirements of different types. In addition to the essential nutrients required by the fungi, traces of complex organic substances are necessary for the growth of certain species or strains which are unable to synthesize them from simple carbohydrates and salts Both the elements and these organic growth substances have been shown or suspected to be essential components of various enzyme systems.

Concentration of the medium

It may control the type of spore, its morphology or the spore-bearing structure. Thus, both *Phycomyces blakesleeanus* (Leonian and Lilly, 1940) and *Sporodinia grandis* (Baker, 1931) require more carbohydrate for zygospore production and maturation than for sporangia. Goldring (1936) showed that with low food supply *Blakeslea trispora* produces sporangia only, while both sporangia and sporangioles are produced at higher concentration. It is not improbable that the pathway of metabolism leading to reproduction differs from that leading to mycelial development only. Bachmann (1895) found that the sporangioles of *Thamnidium elegans* become larger and contain more spores when the organism is grown under conditions of good nutrition. In contrast to this the terminal many-spored sporangia become single-spored if the organism is grown under poor nutritive conditions.

Often the effect of nutrition on sporulation may be that high concentrations of available food stuffs, particularly hexose sugars, inhibit sexual fruiting and may actually stimulate asexual reproduction. Complex organic substances may favour fruiting, which also requires higher concentration of certain minerals in the medium and of vitamins within the mycelium than are sufficient for mycelial growth.

Carbon

It has been shown by Lopriore (1895) that accumulation of CO_2 inhibits sporulation of *Mucor mucedo*, which fails to produce sporangia, a concentration of 10 per

cent CO_2 retards germination of spores of *Mucor mucedo* and undiluted gas produces total inhibition, but even a long exposure to undiluted CO_2 for three months does not kill the spores CO_2 also influenced the development of conidia or sporangia in *Choanephora cucurbitarum* (Barnett and Lilly, 1952) Brown (1922) also confirmed that 10 per cent CO_2 reduced the germination and 30 per cent inhibited it for most fungi He, however, observed that the germination of *Mucor* sp and *Rhizopus nigricans* was inhibited below 20 and 30 per cent, respectively He further established that the toxicity of CO_2 was less on nutrient solutions The corresponding figures for *Mucor* sp and *Rhizopus nigricans* on dilute turnip extract were 40 and 60 per cent, respectively CO_2 can, however, be assimilated by some Mucorales Foster *et al* (1941) showed that *Rhizopus nigricans* can assimilate CO_2 under both aerobic and anaerobic conditions They used radioactive CO_2 The mycelium was suspended in 5 per cent glucose solution and agitated in a closed system containing isotopic CO_2 The mycelium and medium were ultimately analysed for radioactivity More than 33 per cent of CO_2 assimilated was incorporated in cell constituents, which were not decomposed by boiling for one hour with 2M hydrochloric acid

Weimer and Harter (1921) studied the response of various fungi, including *Rhizopus tritici* and *Mucor racemosus*, to glucose, and concluded that the amount of sugar required to produce a unit of dry weight differed with the organism

Marshal (1942) established that *Rhizopus suinus* removed 5 per cent glucose from the medium in four days and the entire quantity (0 5 per cent present in the medium) in nine days

In general, mannose is inferior to glucose for most fungi The results with galactose are variable Corum (1942) showed that it gives good growth of *Rhizopus suinus*.

Margolin (1942) found that *Blakeslea trispora* could utilize glucose, fructose, mannose, galactose and maltose The growth was poor on sucrose and lactose *Mucor racemosus* had best growth on maltose, next best on lactose, fair on glucose and poor on sucrose The growth of *Phycomyces blakesleeanus* was very poor on lactose, fair on galactose and good on other hexoses The growth of *Rhizopus nigricans* was poor on sucrose and lactose, while it was more or less similar on others, *Rhizopus, suinus* had poor growth on maltose, sucrose and lactose Waksman (1931) stated that where sucrose is a source of energy, the medium is rendered unfit for the growth of a great majority of the Mucorales It has been suggested that the nonutilization of lactose by *Syncephalastrum racemosum* was evidently due to the failure of the fungus to synthesize lactase because this organism could grow well on glucose as well as on galactose (hydrolytic products of lactose) The same argument applies to *Blackeslea trispora, Rhizopus nigricans* and *R suinus* Lactose and melibiose were found to be poor disaccharides for all the six Mucorales investigated by Raizada (1957)

Hydrolysis of oligosaccharides by some fungi can easily be demonstrated *Phycomyces blakesleeanus* utilizes sucrose, while *Mucor ramannianus* fails to do so If the mycelium of *P. blakesleeanus* is removed from the flask containing sucrose medium after the fungus has grown in it for several days and the flask is reinoculated with *M ramannianus* the latter fungus will grow *P blakesleeanus* excretes sucrose in the me-

dium which catalyses the hydrolysis of sucrose to D-glucose and D-fructose, both of which can be utilized by *M ramannianus*

Blakeslea trispora has better growth on D-xylose than on L-arainose Similar results have been obtained for *Phycomyces blakesleeanus*, but the growth of *Mucor ramannianus* is similar on both the substances

The effect of various sugar alcohols has also been studied for some members of this order and it has been reported that *Blakeslea trispora* has comparatively poorer growth on these than on corresponding sugars Thus the growth on D-glucose was found to be 90 mg, on sorbitol 12 mg, on D-mannose 98 mg, on mannitol 9 mg, on D-galactose 123 mg and on galactitol 10 mg The corresponding figures for *Mucor ramannianus* were, D-glucose 89 mg, sorbitol 93 mg, D-mannose 150 mg, mannitol 149 mg, D-galactose 116 mg, and galactitol 6 mg. In general, the fungi behave like *Blakeslea trispora* and utilize the corresponding sugar with greater facility than the sugar alcohol, but *Mucor ramannianus* behaves differently, and even in *Phycomyces blakesleeanus* the difference between mannose and mannitol is not very great.

Leonian and Lilly (1940) found that acetic acid, lactic acid, succinic acid, glutamic acid, tartaric acid and citric acid increased the growth of *Phycomyces blakesleeanus* and *Mucor ramannianus*. Raizada (1957) found tartaric acid to be of less use for all the Mucorales studied by him, except *Mucor fragilis*, which could use it poorly.

Margolin (1942) reported that the effect of mixed carbon sources on growth of *Phycomyces blakesleeanus* was purely additive

Certain fungi, such as *Phycomyces* sp., grow most luxuriantly on media containing fat. In general, carbon compounds other than carbohydrates, such as higher alcohol, organic acids, or organic nitrogen substances, are not suitable for spore production. It is either due to the inability of the fungus to use them at all, or when they are used, to the rapid development of unfavourable pH values in the medium. According to Raizada (1957) there was a distinct correlation between growth and sporulation of members of Mucorales studied by him The sporulation was good whenever the growth was good.

Nitrogen

On the basis of nitrogen requirements, Robbins (1937) grouped the fungi under four different heads: Those (1) able to utilize organic nitrogen alone; (2) using organic nitrogen and ammonia; (3) able to utilize nitrates besides organic and ammonium nitrogen; and (4) able to fix even atmospheric nitrogen.

It was, however, established that this grouping was valid only under certain conditions, because the ability to use a particular source of nitrogen depended on the nature of carbon source and other factors Hagem (1910) showed that *Mucor griseocyaneus*, *M. racemosus*, *M. christianensis*, *M. spinosus* and *M. sphaerosporus* could use either ammonium or nitrate nitrogen in presence of glucose. The last two organisms were unable to use ammonium nitrogen even when glucose was replaced by mannitol. It was found by Schopfer (1934) that *Phycomyces nitens* was capable of growing on ammonium salts but it grew better if asparagine was added to the medium. Raizada (1957)

reported that sodium nitrite, which is toxic to most fungi, was good source of nitrogen for *Cunninghamella echinulata*, *Mucor fragilis* and *M hiemalis*

Saida (1901) mentioned that *Mucor stolonifer* can fix atmospheric nitrogen (cf Dugger and Davis, 1916), but it has rightly been pointed out that Saida's investigations need confirmation, specially because his results with some of the other organisms have not been confirmed by other investigators and even contradictory results have been obtained. Lilly and Barnett (1951), therefore, concluded that no member of Mucorales can use atmospheric nitrogen directly

Absidia coerulea*, *A cylindrospora*, *A dubia*, *A glauca*, *A orchidis*, *Mucor flavus*, *M hiemalis*, *M nodosus*, *M pyriformis*, *M saturninus*, *M stolonifer*, *Phycomyces blakesleeanus*, *Rhizopus nigricans and *Zygorhynchus moelleri* can use ammonium nitrogen

Many members of this order, including *Mucor javanicus*, *M rouxianus*, ***Rhizopus nigricans*, *Circinella simplex***, *Absidia simplex* and *Choanephora cucurbitarum*, can easily assimilate organic nitrogen Ronsdorf (1931), Schopfer (1931) and Robbins (1939) showed that high concentration of asparagine inhibit zygospore formation in *Phycomyces blakesleeanus* and it increased vegetative growth Robbins showed that the amount of asparagine needed for producing progametangia was greater than the quantity which was sufficient to prevent the formation of mature zygospores from those structures. He suggested that vigorous vegetative growth with high concentration of asparagine leads to the exhaustion of growth substances in the medium due to which reproduction is prevented The addition of certain plant extracts which presumably contain growth substances reduced inhibiting effect of asparagine Addition of gelatine to a suitable medium also prevented zygospore formation (Schopfer, 1931).

Leonian and Lilly (1938) observed that *Blakeslea trispora* could grow on nitrite even though nitrites are generally poisonous to fungi A few years later (1940) they studied the reciprocal effect of varying amounts of ammonium nitrogen and succinic acid on the growth of *Phycomyces blakesleeanus* which could not utilize nitrate nitrogen They observed that within certain limits the amount of growth was directly proportional to the amount of succinic acid in the medium

The role of four carbon dicarboxylic acids in the nitrogen assimilation has been explained on the basis of their transformation into keto acids

Brain *et al* (1947) mentioned that *Phycomyces blakesleeanus*, etc, which make limited growth on ammonium nitrogen, do so because they are unable to synthesize adequate amounts of 3, 4 and 5 carbon keto acids.

The source of nitrogen may also influence the sporulation of a fungus, and some fungi fail to develop a particular type of spores unless they are supplied with a suitable substance. Thus, *Sporodinia grandis* requires comparatively complex nitrogen compounds (asparagine+peptone, etc) for the production of zygospores. *Choanephora cucurbitarum* has more sporulation on organic nitrogen which is not so good for growth.

Mineral salts

Our knowledge about the effect of various mineral salts on the growth and sporulation of Mucorales is very incomplete. Only scanty information is available. In

general, when any essential element is insufficient the sporulation tends to be low before the growth is inhibited The amount needed for sporulation is greater than that for vegetative growth

Phosphorus Marshal (1942) has observed accumulation of comparatively high quantities of phosphorus in cells of moulds and yeasts, including *Rhizopus suinus.* They, therefore, need sufficient amount of this substance which must be added to the medium in adequate quantity It plays a part in the initial breakdown of sugar through the process of phosphorylation.

Zinc · According to Niethammer (1938), the development of the zygospores of *Rhizopus nigricans* is inhibited in complete absence of zinc This is also needed by *R suinus* Ward (1902) pointed out that zinc acts as a catalyst in the formation of fumaric acid from glucose Lockwood *et al* (1936) found that in absence of zinc, *R oryzae* sporulated on the thirteenth day, but the sporulation started on the third day if zinc was added to the medium

Calcium Young and Bennett (1922) concluded that calcium was beneficial for the growth of most fungi, including *R. nigricans.*

Iron Benecke (1895) found that iron was essential for growth as well as sporulation of various species of *Mucor* Bortels (1921) used refined technique and confirmed these results

Manganese: McHargue and Calfee (1931) reported that the growth of *Rhizopus nigricans* increased with addition of manganese to the culture medium

Arsenic Challenger *et al* (1933) found that *Mucor mucedo* and *M racemosus* were capable of liberating volatile arsenical products when grown on arsenic-containing wall paper

Certain species of *Rhizopus* and *Cunninghamella* have been used to evaluate mineral elements like P, K, Mg, Cu, Zn and Mo in soils, plant materials and culture media Pharis worked with two strains of *Cunninghamella blakesleana* to study the samples of surface soil from four plots upon which the plants exhibited mineral-deficiency symptoms. He found that fungal growth of both the strains was positively correlated with the amount of P and N in the soil sample as determined by chemical analyses He concluded that both the strains were suitable for qualitative determination of P and K

Vitamins and sex hormones

Schopfer (1913, 1932) found that *Phycomyces blakesleeanus* failed to grow on synthetic media containing glucose, asparagine, salts and micro-elements unless thiamin was added to it Subsequently, he (1934) established absolute deficiency of thiamin in this case and found that no environmental condition could permit its synthesis by organism He further established the need of thiamin by several Mucorales, including *Absidia ramosa, Chaetocladium brefeldii, Choanephora cucurbitarum, Dicranophora fulva, Mucor ramannianus, Parasitella simplex* and *Pilaria anomala.* He also observed that *Phycomyces blakesleeanus* required thiamin for vegetative growth and it did not produce zygospores in a liquid glucose-asparagine medium to which this vitamin was added, but the addition of an impurity present in certain samples of maltose

or an extract of wheat germ to that medium induced development of numerous zygospores Similar results were obtained if glucose-asparagine thiamin medium was solidified with agar This factor was termed Z, and was supposed to be present in various plant extracts Factor Z can be fractioned into two groups Z_1 and Z_2 Each of them was found to be useful alone, but was more so when both were present together The chemical properties of factor Z_1 resembled more with those of hypoxanthine than with guanine and that this factor may be considered indentical to the former The nature of factor Z_2 is not known

Robbins and Kavanaugh (1942) mentioned that some known stimulants may eliminate need for certain factors ordinarily supplied by the natural media for germination of spores of *Phycomyces* Thus, an addition of an extract of potato or other natural products of hypoxanthine acetate or some other organic acid to mineral-dextrose agar with thiamin increased spore germination from 12 to 100 per cent *Rhizopus nigricans* is selfsufficient and, therefore, grows without its external supply In fact it is unique in being adversely influenced by external supply of thiamin (Robbins and Ma, 1942) Schopfer (1944) found that addition of inositol could overcome the inhibitory effects of thiamin on *R suinus* It has been shown that *Phycomyces blakesleeanus* is capable of utilizing thiamin or of synthesizing it when furnished with a mixture of two thiamin moieties

Mucor ramannianus is capable of synthesizing only the thiamin-pyrimidine and complete the synthesis of thiamin when it gets thiazole moiety Other Mucorales, deficient in thiamin or its moieties are *Blackeslea trispora, Choanephora cucurbitarum, Mucor ramannianus* and *Phycomyces blakesleeanus* Some species/of *Mucor* have been found to oxidize sterols to cortisone

Schopfer (1933) found that the spores of *P blakesleeanus* did not germinate on agar media on which the fungus had grown, but they could germinate after its autoclaving Thus the substance was either unstable or volatile, but he could not identify it

Nielsen (1931) showed that culture media in which *Mucor suinus* had grown before contained some substance which stimulated the growth of *Aspergillus niger*

Robbins and Kavanaugh (1938) found that *Phycomyces nitens* could grow on a nutrient solution containing dextrose, asparagine and mineral salts if 30 units of pyrimidine and thiazole were added, but neither of those intermediates could be effective in the absence of the other.

Leonian and Lilly (1940) reported that *Rhizopus suinus* could synthesize thiamin when grown in substrate of inorganic salts, amino acids and dextrose *Phycomyces blakesleeanus* could also form thiamin on the same medium, but it could do so only when pyrimidine and thiazole were available It has also been established that *Mucor ramannianus* and *Rhizopus suinus* could synthesize their own biotin

Kogl and Kosterman (1934) noted the presence of heteroauxin in *Rhizopus nigricans*, which appeared to have been formed during the breakdown of tryptophane

Barnett and Lilly (1950) studied the effect of different concentrations of glucose +biotin on the development of conidial heads of *Choanephora cucurbitarum* They found that at the same concentration of glucose the conidial heads increased with an

increase in the amount of thiamin. This increase was very pronounced at very low concentrations of glucose.

Vitamins have also been found to influence the respiration rate of many Mucorales. According to Burgeff (1924), a zone of restraint develops when + and — hyphae of *Mucor mucedo* approach each other and that zone is penetrated by a few hyphae from each colony. It is presumed that some diffusible or volatile substance (or substances) produced by a particular strain influenced the opposite type in advance of actual contact and produced both inhibiting and stimulating effects. He then separated the + and — strains by a permeable collodion membrane and showed that the initial restraint effect (telemorphosis) and the mutual approach of the hyphae of opposite strain (zygotropism) still took place. He obtained similar results for *M. hiemalis*, *Rhizopus nigricans* and *Phycomyces nitens*, but no effect was obtained when two colonies of the same strain were grown in a similar manner.

Verkaik (1930) claimed that only the — strain of *M. mucedo* produced the diffusible substance capable of attracting the other strain, but his work needs confirmation as his technique was faulty. Kohlar (1935) confirmed Burgeff (1924), and reported that both the strains produced diffusible substance. Kohl (1937) also confirmed Burgeff's results. Ronsdorf (1931) obtained similar results with membrane technique for *Phycomyces blakesleeanus*, but she could not get these results on extracts of mycelia, even though she observed that the intensity of sexual response increased in presence of histamine. Krafczyk (1931, 1935) demonstrated attraction of hyphae of opposite strain and initiation of gametangial initials in *Pilobolus crystallinus* without any physical contact.

Burnett (1953) obtained additional evidence for the production of mutually stimulating substances by heterothallic mycelia of *Mucor hiemalis* and *Phycomyces blakesleeanus*. He found that the consumption of O_2 increased significantly just before two approaching colonies of opposite strain came into contact.

Burgeff (1924) suggested, without any experimental support, that the stimulus may be air-borne. Raper (1952) and Banbury (1954, 1955), however, could not confirm this. They suggested that it was only due to diffusible substances. Banbury (1955) found that in contrast to the stimulus controlling zygospore formation, that controlling the direction of growth (zygotropism) could be transmitted through air for a small distance.

Although it is clear that the mutual stimulation of opposite strains of heterothallic species of Mucoraceae is due to complementary hormones, their nature is obscure. Satina and Blakeslee (1925, 1926 a,b) reported some chemical differences between opposite strains. Their work has never been successfully repeated, and many workers feel that their conclusions were based on insufficient evidence. Foster and Waksman (1939) found that the + strain of *Rhizopus nigricans* produces abundant fumaric acid while the — strain failed to produce it at all, but it is most likely that this is not the stimulating hormone. It is further felt that such substances must be highly labile due to which they are destroyed probably by oxidation, as soon as they separate from living mycelium.

Burgeff's (1924) report about the infection of the + strain of the host by the—

strain of *Mucor* (*Parasitella*) *simplex* and vice versa may not be an attempt of hybridization as suggested by him, but may be due to the nutritive needs of the two strains of parasites being differently satisfied by presumably chemically different strains of the host

Hawker (1942) observed that the respiration rate of *Phycomyces blakesleeanus* was greatly increased by addition of thiamin Schopfer (1943) pointed out that the vitamins actually decreased the dry weight of *Rhizopus suinus* but the CO evolved was more.

William and Horn (1932) observed that the addition of yeast extract to the media stimulated the growth of *Mucor racemosus* and some other fungi

Enzymes. Davison and Williaman (1927) studied the pectic enzymes of some fungi, including *Rhizopus tritici* and they confirmed the results of other investigators according to which pectic substances are complex carbohydrate derivatives composed of three types of derivatives

According to Wolf and Wolf (1947), certain moulds, such as *Aspergillus niger, Penicillium glaucum* and *Rhizopus nigricans*, are omnivorous by virtue of their ability to produce large number of enzymes representing each of the groups—carbohydrases, proteases, lipases, oxidases and reductases

Hao *et al* (1943) studied the amylase production of 27 fungi and reported that *Rhizopus delemar* and *R oryzae* were two of the three organisms which produced the largest amount of this substance

Synthesis of acids. Many species of *Phycomyces* and *Rhizopus* produce lactic acid; they include *Rhizopus arrhizus, R chinensis, R elegans, R japonicus, R nodosus, R oryzae, R pseudochinensis, R salebrosus, R shanghaiensis, R stolonifer, R tritici* and *Mucor rouxii* Mostly they synthesized *σ* lactic acid, but Saito (1911) found that *R chinensis* could systhesis *l*-lactic acid Lockwood *et al* (1936) and Ward *et al* (1936, 1938) extensively used *R oryzae* for lactic acid synthesis Waksman and Foster (1938) found that members of the *arrhizus* group were very efficient lactic acid formers, specially when they were grown in solutions containing glucose or starch Of these, 70-75 per cent were converted to lactic acid in presence of calcium carbonate which is generally used for neutralizing the lactic acid, as it is formed In general, glucose has been found to be the best sugar The yield increases if the cultures are suitably aerated Ten per cent sugar solution gives 40 per cent yield with *R japonicus*

It has been observed that the growth of the fungus increases when zinc is added to the medium, but the yield of lactic acid decreases Generally, the acid is most freely produced under sub-optimal conditions of growth of the various organisms

Citric acid Von Loesecke (1945) listed a number of fungi which could be used for commercial production of citric acid and *Mucor pyriformis* was one of them The high yields of citric acid were found to be correlated with their mats of mycelium and light sporulation

Fumaric acid With a few exceptions, fumaric acid is mostly synthesized by species of *Phycomyces* Foster and Waksman (1939) studied the factors influencing its production by *Rhizopus nigricans* They observed that the concentration of zinc was particularly important It was also noticed that some strains could produce it

under anaerobic conditions only while others could do so both under aerobic and anaerobic conditions Hawker (1950) stated that 'when a strain of *Rhizopus nigricans* was grown on glucose solution saturated with CO_2 in which the carbon was radioactive isotope, fumaric acid was produced containing the labelled carbon isolate in the carboxyl group'

Foster and Davis (1948) postulated that strains of *R nigricans* which produce fumaric acid do so according to a definite scheme This has been summarized by Lilly and Barnett (1951).

Succinic acid. Fitz (1873) reported the presence of succinic acid during alcoholic fermentation caused by *Mucor mucedo*

Fermentation. Certain species are capable of fermenting grape juice. Lendner (1908) mentioned that the following species of *Mucor* produced the amount of alcohol indicated in each case: *Mucor janssenii*, 3 41 per cent, *M lamprosporus*, 3.71 per cent; *M. javanicus*, 2 83 per cent, *M plumbeus*, 4 62 per cent, *M pirelloides*, 1.06 per cent; *M. racemosus*, 4.62 per cent, *M rouxianus*, 5 25 per cent, *M griseo-cyaneus*, 4 per cent; and *M. genevensis*, 5 21 per cent.

Fitz (1873) also reported that *Mucor racemosus* was capable of transforming sucrose into alcohol. *Rhizopus nigricans*, *R. tritici*, *R. arrhizus* and *R. oryzae* were also capable of producing ethyl alcohol.

More rapid fermentation is carried on by living cells than by cell-free extracts. According to Harden and Young (1905, 1908), the addition of inorganic phosphates to suspension of living cells does not increase the rate of fermentation. The phosphoric esters are broken down to produce the next intermediate products; then the phosphate again becomes available to phosphorylize more glucose This is a continuous process till all the glucose is exhausted.

IV. EFFECT OF EXTERNAL FACTORS

Light. Moulds and fungal spores are generally more resistant to lethal effects of light than bacteria. The prevalence of fungal spores in the upper atmosphere was explained on this basis by Weinzirl (1921). The effect of light and darkness as well as of light of different intensity or wave length on the growth and other characters of some members of Mucorales was studied by various persons. Elfving (1890) reported that the inhibition of growth due to light varied with the composition of the medium on which the organism was growing. The sporangia of many species of *Mucor* and related genera can sporulate equally well in light and darkness.

Barnett and Lilly (1950) established that a strain of *Choanephora cucurbitarum* needed both light and darkness for development of conidia, though they had no effect on the formation of sporangia. Conidia were neither developed in continuous light (65 foot-candles) nor incontinuous darkness. It was also observed that continuous light of low intensity (less than 1 foot-candle) permitted the development of conidial heads in the usual time. Christenberry (1938), who studied another isolate of the same fungus, reported that the sporulation was best in alternate light and darkness of 12 hours each, but his strain could develop conidia even in complete darkness. He also observed that red-yellow light was more favourable for the development of conidia than the light of shorter wave length.

According to Elfving (1890), strong light depressed the growth as well as the length of the sporangiophores in *Phycomyces blakesleeanus*. Brefeld (1881) found that the sporangiophores in *Pilobolus* continue to grow in absence of light, but the sporangia are not formed. Even a shorter exposure of two hours permitted continued development of partially formed sporangiophores. Both the sporangia and sporangiophores developed normally in blue light but failed to do so in red-yellow light.

Buller (1934) studied the spore discharge of various species of *Pilobolus*, though *P. kleinii* and *P. longipes* were more extensively used by him. McVickar (1942) observed that the sporangia of different species of *Pilobolus* mature at definite time each day, and this is related to the stimulus of light which can be confirmed by exposing the cultures to different combinations of light and dark periods. Brefeld (1877) reported that the discharge of spores of *Pilobolus* could be delayed by placing the cultures in darkness. Lendner (1897) made an interesting observation that *Mucor flavidus* could form sporangia on solid media in darkness, but under similar conditions it failed to do so on liquid media.

Stevens (1930) reported that sporulation may be inhibited by sublethal degree of illumination or the growth and sporulation may be stimulated in a zone immediately surrounding the illuminated area. *Mucor guilliermondii* produces numerous sporangia in such a zone, while *M. genevensis* produces zygospores in such numbers as to form a black border to the killed zone.

Some attention has been given to the wave length of light on sporulation but the results so far obtained are contradictory and difficult to explain. Christenberry (1938)

claimed that red-yellow light is most effective in stimulating production of conidia by *Choanephora*, while blue light is most effective in causing increased growth and consequent phototrophic curvatives in sporangiophores of *Phycomyces* sp investigated by Blaauw (1914, 1919) and Castle (1928, 1933) Parr (1918) obtained similar results for *Pilobolus* sp These two organisms produce the orange-coloured pigment carotene Bunning (1937) suggested that carotenoids may be the light-sensitive substance postulated by Castle (1931, 1932) According to Page (1956), one of the light-sensitive substance in *Pilobolus* is a flavin

Nadson and Phillippov (1925) supressed the formation of zygospores of *Zygorhynchus moelleri* and *Mucor genevensis* by exposing them to X-rays. Dickson (1932, 1933) exposed maltagar cultures of *Mucor genevensis* and *Phycomyces blakesleeanus* to X-ray for 50 minutes at a distance of 26 cm He noticed that the changes were induced in the colour and the amount of mycelium Sectors were produced in subcultures.

The length of exposure to ultraviolet light must be clearly stated as it is very important The medium on which the organism is growing, the age of the culture and increase of temperature due to ultraviolet exposure greatly influence the results. It has been observed that mutations are readily induced in many fungi exposed to sub-lethal conditions. In general, a treatment with X-ray and ultraviolet light causes mutation in most living organisms

According to Schulze (1909), the hyphae of *Mucor stolonifer* exposed to sub-lethal doses of ultraviolet light become densely granular with swollen tips It has been observed that irradiation with diffused ultraviolet light (2,900A) permits growth at a normal rate for some time which is then retarded With continuous irradiation the growth rate falls progressively till it stops. The hyphae do not regain the power of growth even when irradiation stops. If, however, the irradiation ceases before the growth stops, the rate may continue to fall and may even reach zero, but the hyphae resume growth after an interval. Diamond and Duggar (1941) determined the lethal effect of monochromatic ultraviolet radiation (2650A in wave length) on *Rhizopus suinus* and *Mucor dispersus*. They correlated the ergs of energy required with volumes of the spores.

Fulton and Coblentz (1929) tested the use of ultraviolet rays as potent fungicides. They took 110-volt quartz-lamp with mercury cathode and tungsten anode operated on 320 watts (80 volts, 4 amp). The spores of the organisms tested were on the surface of agar medium They took care to eliminate the temperature effect and found that some fungi could survive, but *Rhizopus nigricans* was killed.

Temperature. It is a major factor restricting the distribution of many fungi. It often influences sporulation due to its effect on a number of metabolic processes or by modifying the physical nature of the substrate Weimer and Harter (1923) worked with many species of *Rhizopus* and confirmed the above finding of previous investigators. Klebs (1900) pointed out that the temperature range which allowed sporulation was narrower than the range for growth (Table I) It was also reported that the temperature range for sexual reproduction was narrower than the range which permitted asexual reproduction Stevens and Hall (1909) established that the temperatures which permitted growth were lower than those which allowed germination

TABLE I THE RANGE OF TEMPERATURE SUITABLE FOR GROWTH AND SPORULATION OF SOME MEMBERS
(The name of the investigator is given within parentheses)

Fungus	Growth Min	Growth Max	Sporulation Min	Sporulation Max
Sporodinia grandis (Klebs, 1900)	1–2	31–32	5–6	29–30
Pilobolus microsporus (Grantz, 1898)	2–4	33–34	10–12	28–30
Mucor racemosus (Klebs, 1900)	4–5	32–33	6–7	30–31
Mucor sexualis (Hawker, 1957)	1		5	

R. artocarpi	27.5°C	*R. nodosus*	34.0°C
R. nigricans	25.0°C	*R. ordosus*	32.0°C
R. reflexus	27.0°C	*R. arrhizus*	35.0°C
R. microsporus	25.0°C	*R. maydis*	32.0°C
R. tritici	34.0°C	*R. chinensis*	40.0°C
R. delemar	32.0°C		

Barnett and Lilly (1950) found that temperature influenced the type of asexual reproduction in *Choanephora cucurbitarum*. Eighty-seven per cent conidial heads and 13 per cent sporangia were observed at 25°C, but their proportion was nearly reversed at 30°C, and at 31°C the conidia were not formed though many sporangia were produced. Sporulation was absent at 34°C even though there was sufficient vegetative growth. The size of sporangia was also influenced by temperature. The average diameter was 60μ to 90μ at 25 C while at 30° or 31 C it was 145μ.

Robbins and Schmidt 1945) found that the incubation temperature influenced zygospore formation in *Phycomyces* because of the amount of acid formed in the medium. Zygospores were not formed on glucose asparagine medium at 26°C but they were developed at 20°C.

Zycha (1935) distinguished between certain species of *Mucor* on basis of their response to various temperatures. Castle (1927, 1928) showed that the effect of temperature on the growth of sporangiophores of *Phycomyces* is irreversible and previous exposure to a particular temperature does not influence the rate of growth after transfer to another temperature.

The various temperatures which permit growth of these fungi have also been determined. Spores of *Cunninghamella elegans* failed to germinate at 1°C and its optimum temperature was found to be 35°C, but it could germinate well even at higher temperature. Weimer and Harter (1923) found that the minimum, optimum and maximum temperatures for the sporangiophores of *Rhizopus nigricans* was 1.5°C, 26°–28°C and 33°C respectively. Its spores germinated satisfactorily at 3°C. *Rhizopus chinensis* was found to tolerate higher temperatures than any of the other 10 species studied by them.

Becquerel (1910) dried the conidia of some fungi, including *Mucor* and *Rhizopus*, sealed them in tubes under vacuum in which the pressure was reduced to 10^{-4} cm of mercury, and exposed them to -190°C for 77 hours. The conidia could germinate normally even after a storage of two years. Lipman (1937) cultivated 12 species of fungi which, included *Mucor, Rhizopus, Absidia* and *Mortierella*, on synthetic agar or potato agar for 24 hours and after gradual cooling immersed them in sealed tubes in liquid air for 48 hours and then gradually warmed them. He found that eight of them survived. Ames (1915) found that the thermal death point of *Rhizopus nigricans* was 60°C. He also reported that it needed 168 hours to germinate at 6°C, 43 hours at 12°C, 36 hours at 15°C, 16 hours at 20°C, 13 hours at 25°C and 16 hours at 30°C.

The following records give the optimum temperatures for the growth of various species of *Rhizopus*:

R. artocarpi, 27.5°C	*R. nodosus*, 34.0°C
R. nigricans, 25.0°C	*R. oryzae*, 32.0°C
R. reflexus, 27.0°C	*R. arrhizus*, 35.0°C
R. microsporus, 25.0°C	*R. maydis*, 32.0°C
R. tritici, 34.0°C	R. *chinensis*, 40.0°C
R. delemar, 23.0°C	

Hawker (1950) recorded the cardinal points of various species of *Rhizopus*.

Barnes (1935) induced variation in *Thamnidium elegans* by exposure to temperatures just sufficient to kill it. It was noticed that exposure to high temperatures induced non-reversible changes in the colonies.

Baker (1931) reported that *Sporodinia grandis* developed zygospores at higher temperatures than those which favour the formation o sporangia. It has also been observed that the sporangia of *Mucor sexualis*, etc., develop at temperatures that are too low for zygospore formation.

Barnett and Lilly (1950) showed that the effect of temperature on spore production of Mucorales is very complex. It has been shown by Perkins (1952), Roberts (1954) and Hawker (1954) that the inhibiting effect of low temperature on zygospores formattion of *Mucor sexualis* acts only at early stages. There is some evidence to show that the effect of low temperature is due to inhibition of some synthetic process because the gametangia may continue to develop in the presence of old zygospores of the same or a related species. Extracts from old cultures were not effective, this indicates that the hypothetical substance is labile and is destroyed by exposure to air, etc. The addition of small amount of adenine or some other purines induces a few but not all young gametangia to continue their development. The effect is enhanced by thiamin (vitamin B_1). Biotin has no obvious effect. These substances cannot replace the effect of having mature zygospores or of high temperature.

Aeration. It has been observed that in the absence of artificially introduced fungicidal gases the concentration of CO_2 is the most important factor controlling the effect of poor aeration on the quantity of growth as well as on the morphology of spores and sporophores. Barnett and Lilly (1950) mentioned that *Choanephora cucarbitarum* developed numerous conidial heads in well-aerated dishes. Their number decreased

in tightly fitted petri-dishes Sealing of the dishes completely prevented the formation of conidia

Respiration It has been established by Hawker (1944) that an early increase in respiration is correlated with increased and earlier fruiting in various fungi, including *Phycomyces blakesleeanus* Burnett (1953) showed that respiration rate of + and — strains of heterothallic *Mucor* increased as the colonies approached one another prior to conjugation

Humidity. Both water content of the substrate and humidity are important. Walter (1924) showed that the rate of growth of the sporangiophores of *Phycomyces nitens* is influenced by humidity and fluctuates in response to sudden changes An increased humidity caused increased growth rate, which gradually came down to the original rate Decreased humidity was followed by decreased rate which also returned to the normal The sporangiophores curve away from local damp areas owing to greater growth of the side nearest the source of moisture Generally, sporulation takes place at wetter conditions than those required for growth and it is more necessary to have higher humidity Barnett and Lilly (1955) found that relative humidity and temperature influenced the relative number of conidial heads and multispored sporangia of *Choanephora cucurbitarum* At 25°C and above sporangia predominated at a relative humidity of 100 per cent but conidia predominated at lower relative humidity Klebs (1898) established that zygospores of *Sporodinia grandis* were produced at 100 per cent relative humidity while the sporangia were developed at lower relative humidity These results were confirmed by Robinson (1925) but Baker (1931) reported that both spore forms could develop at wide range of relative humidity (from 0–100 per cent) Ingold (1954) found that xeromorphic sporangiophores of *P blakesleeanus* develop in dry atmosphere if the substrate is kept moist

Chemotropism. Fulton (1906) used *Mucor mucedo* as one of the organisms for studying chemotropism resulting from staling products produced by the fungus itself and concluded that the germ tubes turned as much towards pure water and non-nutrient solutions as towards substances which were presumed to act as attractants

Graves (1916) reinvestigated the problem and used *Rhizopus nigricans* He concluded that positive chemotropism is to be regarded as one of the factors which govern penetration, but negative chemotropism is the major factor.

Pigments. Recently attention has been given to the association of carotenoid pigments with one or the other sex in certain fungi Carotenoids are frequently associated with spores and spore-bearing organs and are lacking in the vegetative mycelia of the same species The function of fungous pigments is not well understood, but Schopfer (1935) reported that *Mucor hiemalis*, *Phycomyces blackesleeanus* and possibly *Mucor mucedo* can produce carotene The amount of carotene produced by *P. blakessleeanus* increased with an increase of asparagine in the medium It was also observed by Lendner (1918) that the + strain of *Mucor hiemalis* contained more carotene than the — strain Satina and Blakeslee (1926), Chodat and Schopfer (1927) and Schopfer (1942) claimed that this was also true for *Phycomyces blakesleeanus*, but their results could not be confirmed by Garton *et al* (1950, 1951) They found that the — strain produced twice as much carotene as the + strain Barnett *et al.* (1956) demonstrated

an increased production of carotene by *Choanephora cucurbitarum* when both the + and — strains were present. Barnett (1956) re-examined the evidence for correlation between carotene and sex in *Mucor* and concluded that they were not correlated. The problem is interesting, specially on account of the results obtained with various types, but it is unlikely that it will lead to the elucidation of the mechanism of either reproduction in general or of sex determination in fungi.

Hydrogen ion concentration (pH). The apparent effect of other environmental factors, viz., temperature and nutrition, etc., is often due to indirect change of pH. It plays an important part in the growth of various fungi Clark (1899) studied the effect of concentration of a variety of mineral and organic acids on germination of spores and mycelial development of fungi, including *Oedocephalum albidum*. He found that OH group was more oxic than H group It was also observed that a concentration of 200 to 400 times needed for killing the higher plants was necessary for inhibiting the germination of fungi

Rhizopus nigricans has two optimum pH ranges one on either side of the isoelectric point.

Robbins and Schmidt (1945) found that mature zygospores of *Phycomyces blakesleeanus* were not formed on glucose-asparagine medium at 26°C They, however, appeared when protein hydrolysates, glutamic acid or other amino acids or various organic acids were added to the media because these buffers prevented the fall of pH to a level which prevented zygospore formation. Johnson (1923) determined the pH range of *Mucor glomerula* which was found to be between 3 2–9.2.

CLASSIFICATION

The classification of Mucorales is based on asexual reproductive structures as such, it leaves much to be desired. Various suggestions were made since the order was recognized, but a true phylogenetic classification remains to be completed.

Van Tieghem (1873) recognized only one family, Mucoraceae, but a few years later Fischer (1892) subdivided it into five families. Fitzpatrick (1930) recognized seven families which were separated on the following basis:

I Sporangium when present globose to pyriform, many-spored in some genera accompanied and in others replaced, by few-spored sporangiola or unicellular conidia, zygospore formed in the fusion cell which results from the copulation of the gametangia.

A Sporangium when present containing a columella, zygospores not enveloped by a layer of interwoven hyphae.

1 Sporangium always formed; sporangiola and conidia lacking.

a Sporangial wall thin, not cutinized . . . 1. MUCORACEAE

b Sporangial wall heavily cutinized in upper portion . . 2. PILOBOLACEAE

2. Sporangium either accompanied, or replaced, by sporangiola or conidia.

a Sporangium present, accompanied by sporangiola, both usually formed on the same sporangiophore . . .. 3. THAMNIDIACEAE

b Sporangia often absent, when present solitary, not borne on the same sporangiophore with sporangiola or conidia.

(i) Sporangium absent, conidia covering sub terminal enlargements of branches of the conidiophore 4. CHAETOCLADIACEAE

(ii) Sporangium present in some genera, absent in others, sporangiola or conidia present in all cases, and covering terminal capitate enlargements of branches of the sporangiophore or conidiophore 5 CHOANEPHORACEAE

B Sporangium when present lacking a columella, zygospores where known enveloped by a thick layer of interwoven hyphae, sporangiola and conidia formed in some cases, when present isolated, not covering an enlargement on the sporangiophore or conidiophore 6 MORTIERELLACEAE

II Sporangium narrowly cylindrical or rod-like, relatively few spored, sporangiospores arranged in a single row, at maturity having the aspect of a chain of conidia due to the dissolution of the sporangial wall, zygospores usually formed in a bud put out by the fusion cell which results from the copulation of the gametangia 7 PIPTOCEPHALIDACEAE

Fitzpatrick did not recognize Endogonaceae as a separate family While discussing *Sphaerocephalus*, *Sclerocystis*, *Glaziella* and *Endogone*, he stated 'Whether these four genera should be regarded as constituting a separate family of the Mucorales related to and somewhat higher than the Mortierellaceae is perhaps open to question, but on the present state of knowledge it seems very likely that the group should be incorporated in the Mucorales

Zycha (1935) recognized six families and suggested the following key for their differentiation

A Sporangia single, multispored sporangia always with columellae

1 All sporangia multispored MUCORACEAE

2 Sporangia with two kinds of spore forming apparatus, terminal multicelled sporangia and numerous lateral verticillate sporangiola with few spores THAMNIDIACEAE

B Sporangiola or conidia united on special sporangiophores

3 Spherical, single or many-spored sporangiola on specialized enlargements of the fruiting hyphae .. CHOANEPHORACEAE

4 Long chains of small sporangiola usually on special basal cells, mostly parasitic on Mucorales CEPHALIDACEAE

C All sporangia without columellae, zygote surrounded by thick covering of hyphae

5 Sporangia and zygotes single . . . MORTIERELLACEAE

6 Sporangia or zygotes united in specialized fruiting bodies surrounded by hyphae ENDOGONACEAE

Naumov (1939) proposed the following classification

I SPORANGIOPHOREAE
Mucoraceae
Pilobolaceae
Mortierellaceae

II CHOANEPHOREAE
Choanephoraceae

III PSEUDOCONIDIOPHOREAE
Syncephalastraceae
Cephalidaceae

IV CONIDIOPHOREAE
Syncephalastraceae
Spinaliaceae

It is evident that Naumov also placed much emphasis on the type of asexual reproductive structure and on the types of sporangia or conidia produced by various members. He did not recognize Thamnidiaceae or Chaetocladiaceae which were regarded only as tribes Cunninghamellaceae was separated from Choanephoraceae while Piptocephalidaceae was subdivided into three families, i e , Syncephalastraceae, Cephalidaceae and Spinaliaceae.

Linder (1943) established a new family Kickxellaceae to include the genera *Kickxella, Coemansia* and *Martensella.*

Bessey (1950) recognized eight families. He mainly followed Fitzpatrick (1930) but did not recognize the family Chaetocladiaceae He included two new families Kickxellaceae and Endogonaceae His scheme is given below:

"Asexual sporangia", sporangioles or "conidia" aerial All the sporangia many-spored, with a well-developed columella, sporangial wall relatively thin and breaking or deliquescent MUCORACEAE

All the sporangia many-spored, with a moderate-sized columella, sporangial wall thickened above and not breaking up or deliquescent . . PILOBOLACEAE

Terminal primary sporangium of the sporangiophore many-spored, with a well-developed columella, sporangial wall thin and breaking up or deliquescent, secondary sporangia in the form of few-celled or one-celled sporangioles which are usually indehiscent. Primary sporangia lacking under unfavourable conditions, and never formed in a few genera

Sporangioles on more or less dichotomous branches formed laterally along the main sporangiophore. (Primary sporangium lacking in the genus *Chaetocladium*) THAMNIDIACEAE

Sporangioles on the surface of rounded or elongated heads terminating sporangiophores apart from the primary sporangiophore. Primary sporangium lacking in genera *Cunninghamella, Mycotypha,* etc. . . CHOANEPHORACEAE,

Sporangia spherical, many-spored, with basal septum and no columella . MORTIERELLACEAE

Sporangia narrow, one to several-spored with no columella, usually more or less capitately borne, often breaking apart into one-spored segments PIPTOCEPHALIDACEAE

Sporangia reduced to one-celled, indehiscent sporangioles (conidia) borne singly on sterigmata arranged on one side of a branch (sporocladium) so as to resemble a comb . KICKXELLACEAE

Sporangia, zygospores and chlamydospores in the interior of rounded masses of hyphae, often burried in humus or soil . . . . ..ENDOGONACEAE

Martin (1946) recognized seven families only. According to him they can be distinguished on the following basis.

a Sporocarp present, containing sporangia, zygospores or azygospores .. ENDOGONACEAE
b. Sporocarp lacking . . ENDOGONACEAE
Columellate sporangia present or absent, non-columellate sporangia, sporangioles, merosporangia or modified sporangia functioning as conidia always present .. ..
c Sporangial membranes thin, fugacious, sporangiospores liberated by breaking up of sporangial wall, suspensors rarely tong-like .. MUCORACEAE
c. Sporangial wall densely cutinized above, entire sporangium violently discharged or detached as a whole from sporangiophore, suspensors tong-like .. PILOBOLACEAE
d. Terminal sporangium columellate, multispored or sometimes replaced by sterile spine, sporangioles (few or one spored) borne on whorled branches of some sporangiophore.. THAMNIDIACEAE
d Columellate sporangia lacking (except in Choanephoraceae), imperfect stages represented by non-columellate sporangia, sporangioles, merosporangia or conidia or some combination of these structures.

e Merosporangia borne on swollen tips of sporangiophores, at first cylindrical, then forming a single row of sporangiospores, simulating a chain of conidia PIPTOCEPHALIDACEAE
e Merosporangia lacking
f Sporangioles or conidia borne on swollen tips (columellate sporangia also present in some genera), zygospores naked CHOANEPHORACEAE
f Sporangia, if present, without columella, sporangioles and conidia, when present borne singly, not on swollen tips of sporophores, zygospores embedded in a thick hyphal matrix MORTIERELLACEAE

Rugmini (1956) in her taxonomic studies of the Mucorales of Saugar proposed a key based on Naumov (1939), Zycha (1935), Bessey (1950), Hesseltine (1953) and Povah (1917) She included six families which were separated on the following basis:

A All sporangia columellate, many-spored and alike
a Sporangial wall thin, sporangiospores liberated by breaking up of the sporangial wall 1 MUCORACEAE
b Members coprophilous, sporangial walls highly cutinized, sporangiophores with a swelling at the base—the trophocyst 2 PILOBOLACEAE
B Columellate sporangia present or absent, when present terminal Non-columellate sporangiola, merosporangia or conidia always present
c Terminal sporangium columellate, multispored or sometimes replaced by sterile spine Sporangiola borne on more or less dichotomous branches, formed laterally along the main sporangiophore 3 THAMNIDIACEAE
d Terminal sporangium present or absent, sporangiola borne on terminal enlargements of branches of conidiophores 4 CHOANEPHORACEAE
e Sporangia tubular, one to several-spored with no columella, usually more or less capitate borne after breaking apart into one spored segments 5 PIPTOCEPHALIDACEAE
f Sporangia reduced to one-celled, indehiscent sporangiola (conidia) borne singly on sterigmata arranged on one side of a branch (*Sporocladium*) 6 KICKXELLACEAE

This classification is of interest, specially because no other classification of Mucorales dealing with its various families has been suggested by any other Indian worker. It excludes Mortierellaceae and Endogonaceae recognized by Martin because no member of those families has so far been reported from India

In the light of recent work, Hesseltine (1955) slightly modified Martin's (1946) classification He not only recognized the family Kickxellaceae of Linder (1943) but also accepted the subdivision of Choanephoraceae into Choanephoraceae and Cunninghamellaceae His classification is not only the most modern but is the natural modification of Martin's classification which was followed in other monographs It is, therefore, decided to accept the modifications of Martin's system, suggested by Hesseltine, and follow the same for detailed discussion of the Mucorales

1 Sporocarp present, containing sporangia, zygospores or azygospores ENDOGONACEAE
1 Sporocarps lacking 2
2 Sporangia all columellate and alike 3
2 Columellate sporangia, sporangiola, merosporangia or conidia always present 4
3 Sporangial membrane thin, fugaceous, sporangiospores liberated by breaking up of the sporangial wall, zygospores rough, suspensors usually not tong-like 2 MUCORACEAE
3 Sporangial wall densely cutinized above, entire sporangium violently discharged or detached as a whole from the sporangiophore, zygospores smooth, suspensors tong like PILOBOLACEAE

4 Terminal sporangium columellate, multispored, or sometimes replaced by a sterile spine or both absent, sporangiola (few- or one-spored) borne on branches of the same sporangiophore . THAMNIDIACEAE

4 Columellate sporangia lacking (except in Choanephoraceae), imperfect stage represented by non-columellate sporangia, sporangiola, merosporangia or conidia or some combination of these structures . .. 5

5 Asexual stage represented by merosporangia or conidia borne on phialides on a sporocladium .6

5 Merosporangia lacking, conidia not borne on phialides on a sporocladium .. 7

6 Merosporangia borne on swollen tips of sporangiophores, at first cylindrical, then forming a single row of sporangiophores, simulating a chain of conidia PIPTOCEPHALIDACEAE

6 Imperfect stage with only conidia, conidia borne in phialides which in turn are borne upon a sporocladium, sporocladia often on a branch or directly upon a conidiophore KICKXELLACEAE

7 Sporangiola or conidia borne on swollen tips (columellate sporangia also present in some genera) Zygospores naked .. 8

7 Sporangia, if present, without columellae, sporangiola and conidia, when present, borne singly not on swollen tips of sporophores, zygospores embedded in a thick hyphal matrix . . MORTIERELLACEAE

8 Genera forming conidia only, with zygospores formed as in *Mucor* CUNNINGHAMELLACEAE

8 Genera always possessing sporangia and sometimes conidia, zygospores not formed as in *Mucor* .. . . CHOANEPHORACEAE

V. PHYLOGENY

According to Bessey (1950), the phylogeny of the Mucorales is probably tied up with that of the Zoopagales. Cellulose has not been demonstrated in the mature cell wall of the Mucorales, although it has been observed in the younger mycelium of certain types. There is no doubt that fungus chitin makes up the greater part of the cell in the older mycelium. The presence of cellulose in the younger mycelium and its absence from the older ones has prompted Bessey (*loc. cit.*) to suggest that the ancestors of the Mucorales had little or no chitin in their cell wall. It is further considered that in the asexual reproduction of typical Mucorales the aerial hypha terminates into sporangium within which angular naked cells are developed by cleavage. They then quickly round up and become encysted. They escape from the sporangium by the dissolution or fragmentation of the membrane and may be distributed by water or air currents or even by insects. Except for the non-flagellate condition of the spores, this type of asexual reproduction is found in Blastocladiales, Monoblepharidales and Saprolegniales, as well as in some of the terrestrial and aquatic Peronosporales. The fact that the mycelium of the Mucorales is mostly stout and that a large number of species are soil inhabitants would seem to exclude many of the Pythiaceae, Blastocladiales and Monoblepharidales from consideration. The genus *Aplanes* of Saprolegniaceae develops aplanospores in the sporangium without undergoing the motile stage. Thus, so far as the asexual mode of reproduction is concerned, there may be no serious barrier to derive them from some Saprolegniaceous soil fungus with apalanospores. In general, however, the conjugating gametangia of Mucorales are almost equal in size, while in Saprolegniales they consist of a small antherid and a large oogone, the former usually producing a conjugation tube which penetrates through the oogone wall and opens at its tip when nearly or quite in contact with the egg. No such conjugation tube is, however, formed by *Brevilegnia*, which simply develops an opening through the antherid and oogone walls through which the male nucleus enters. Even the supposed isogamy of the Mucorales is more apparent than real because the nuclei and part of the cytoplasm of one gametangium passes through an opening in the walls into the other gametangium. Thus, we have a functioning antherid although it is equal in size with the oogone. In some cases the fusing gametangia are unequal in size. In *Dicranophora*, one gametangium is very large and the other very small, and the zygospore wall includes the oogone alone or rarely a part of the antherid also. Accordingly some soil-inhibiting members of the Saprolegniales may be regarded as the ancestral form of Mucorales. Due to the presence of parthenogenetic spores and homothallic and heterothallic condition Hesseltine (1952) stressed the similarity in the sexual reproduction of the two orders and he agreed with Bessey's (1950) suggestion.

Jaczewski (1929–30) regarded some members of Chytridiales to be the ancestors of Mucorales. Sometimes Monoblepharidaceae and Cladochytriaceae have also been considered as the ancestral stock of the Mucorales.

Davis (1903) suggested that they might have been derived from isogamous algal

forms which may correspond to *Cladophora* or some other isogamous member of Siphonales.

It is not desirable to speculate much on phylogenetic relationships because the intermediate types are entirely lacking and even the morphological significance of the structures like the sporangium of the Mucorales is not yet clearly understood. Bessey's (1950) suggestion appears to be stimulating but much more work will have to be carried out before a true phylogenetic picture of this order will be available.

VI. ENDOGONACEAE

This family has 26 species which possess 'sporocarps', the latter are moderately firm sclerotium-like bodies a few mm to 2–3 cm in diameter They occur in humus-rich soil, leaf mould or among mosses The hyphae are interwoven and coenocytic, but the older ones may become septate There are three types of reproductive bodies which are scattered throghout the sporocarp, but all types are never present in the same sporocarp, though both the chlamydospores and zygospores may be present in sporocarps of *E fasciculata* and *E occidentalis* True sporangia are entirely lacking Some species develop zygospores which have parallel suspensors and are formed like those of *Piptocephalis* Bucholtz (1912) reported that most of the nuclei in each gametangium of *Endogone lactiflua* degenerate, leaving only one privileged nucleus to unite in the zygospore, but according to Atkinson (1918) many pairs of nuclei unite in *E sphagnophila* Kanouse (1936) found that the mycelium, sporangiophores and sporangia of *E sphagnophila* were similar to those of *Mucor ramannianus* The sporangial wall breaks up quickly in water and sets free the spores leaving a spherical columella Its sporangia differ from those of *E malleola* and *E reniformis* She, therefore, segregated the last two in a separate genus *Modicella*

The other two genera, *Sclerocystis* and *Glaziella*, develop chlamydospores only and differ from *Endogone* in the arrangement of the sporocarp

The earlier mycologists placed this family in various positions among the Ascomycetes, in the Protomycetae, close to the Ustilaginaceae, etc, but on the basis of zygospore formation it was placed under the Mucorales by Bucholtz (1912) It has not been reported from India

VII. MUCORACEAE

This family can be distinguished by its extensive and rapidly growing mycelium; sporangiophores, simple or branched; sporangia multispored, glob se to pyriform; apophysis may be present; columella always present, sporangia neither deciduous nor violently discharged, conidia and true sporangiola absent; sporangial wall usually not cutinized; rhizoids and stolons present, zygospores with roughened wall; isogamous or heterogamous, suspensors not tong-like and may have projections Mostly saprophytic, never obligate parasites

Various members may be found in soil, decaying plant material, dung or they may attack other fungi. Some are also parasitic on higher plants

The family contains 13 genera out of which eight have been reported from India

KEY TO THE GENERA

1 Sporangia flask-shaped with a distinct spherical venter and a long neck 1 SAKSENAEA
1 Sporangia not flask-shaped . 2
2 All sporangia pyriform and with a definite apophysis, sporangia borne from stolons but typically not opposite the rhizoids ABSIDIA
2 Spherical sporangia on upright sporangiophores and pyriform sporangia borne circinately on flaccid sporangiophores PIRELLA
2 All sporangia spherical, if stolons present, then sporangiophores opposite the rhizoids 3
3 Sporangia with definite apophysis . 5
3 Sporangia without apophysis
4 Sporangiophores formed mostly on stolons, opposite the rhizoids RHIZOPUS
4. Sporangiophores not on stolons . SPINELLUS
5 Sporangiophores usually on stolons with rhizoids ACTINOMUCOR
5 Sporangiophores not on stolons . 6
6 Sporangiophores regularly dichotomously branched, sporangia all of the same size, homothallic SYZIGITES
6. Sporangiophores at least partly dichotomously branched, large terminal sporangia and smaller sporangia on branches, homothallic DICRANOPHORA
6 Sporangiophores irregularly divided or simple 7
7 Sporangiophores branched with all branches bearing sporangia circinately CIRCINELLA
7 No sporangia or not all the sporangia on branches borne circinately . 8
8. Large sporangiophores over 80 mm high with metallic luster, unbranched, suspensor with branched finger-like projections PHYCOMYCES
8 Sporangiophores shorter, or, if 80 mm, branched and without metallic luster, suspensors usually unadorned 9
9 Never parasitic on other members of the Mucorales, suspensors unadorned .. 10
9. Gall-forming parasites upon other Mucorales Suspensors with finger-like projections PARASITELLA
10. Zygospores constantly on short side branches of the sporangiophores, homothallic ZYGORHYNCHUS
10. Zygospores on separate hyphae seldom upon sporangiophores, mostly heterothallic, isogamous MUCOR

Genus SAKSENAEA Saksena, S B

Mycologia 45 434, 1953

Sporangia flask-shaped with spherical venter and a long neck, formed singly or in pairs at the end of aerial hyphae, each sporangiophore above a profusely dichotomously branched rhizoidal complex Columella prominent and dome-shaped Sporangia dehiscing by dissolution of an apical mucilaginous plug, spores discharged through this neck

HABITAT : On soil
DISTRIBUTION . India (Saugar), France

Saksenaea vasiformis Saksena, S B

Mycologia 45 434, 1953

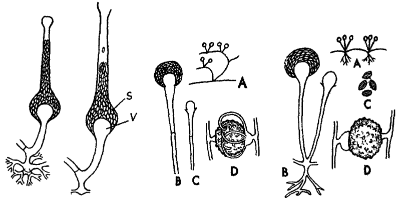
Mycelium well developed, fast growing, with much-branched hyphae of two kinds —submerged and profusely branched, flocculent and aerial, 3 2-6 4 μ broad Sporangia generally single, sometimes in twos, erect, developed at the end of a hyphal branch with a dichotomously branched rhizoidal structure below Rhizoids 3 2-4 8 μ broad, stalked, stalk 6 4-9.6 $\times$ 24-64 μ, flask-shaped with a spherical venter, 16-43 2 $\times$ 22 4-51 2 μ, with distinct dome-shaped columella, venter surmounted by a long neck, 6.4-11 2 $\times$ 54 4-200 μ, apex of the neck slightly broader, 8-14 4 μ in diameter, closed with a mucilaginous plug, sporangiospores walled, oblong, 1 4-2 1 $\times$ 2 8-4 2 μ, discharged through the neck by dissolution of the apical plug Only one germ tube formed during germination (Fig 23)

Sexual reproduction not observed so far
HABITAT . On soil
DISTRIBUTION Patharia forest, Saugar, Canal Zone

Genus ABSIDIA van Tieghem

Ann Sci nat 4 (Ser. 6) . 350, 1876
Syn *Tieghemella* Berlese et de Toni, *Syll fung* 7 181-322, 1888
Mycocladus Beauverie, *Ann Univ Lyon* 3 162, 1900
Lichtheimia Vuillemin, *Bull Soc mycol Fr* 19 126, 1903
Proabsidia Vuillemin, *op cit* 19 126, 1903
Pseudoabsidia Bainier, *op cit* 19 · 453-172, 1903
Protoabsidia Naumov, *Clés des Mucorinées* p 76, 1939

Mycelium forming repeatedly branched arching stolons, rooted at the point of contact with the substratum Sporangiophores erect, straight, usually in fascicles, more rarely single, arising from the elevated arching internodes of the stolons, not opposite the rhizoids Sporangia terminal, pyriform, sporangial wall neither incrusted nor thickened, thin, soon disintegrating Columella conical to hemispherical, with a papillate apical prolongation which is sometimes drawn out into rather long spine. Sporangiospores smooth, zygospores borne on stolons, one or both suspensors provided with prominent circinate outgrowths which tend to envelop the zygospores



23 24 25

FIG 23 *Saksenaea vasiformis* Saksena Mature sporangium filled with spores, S, spores, V, vacuole (After Saksena 1953)

FIG 24. *Absidia*. A, habit, B–C, sporangiophores, D, zgyospore (After Lendner)

FIG 25 *Rhizopus* A, habit, B, sporangiophores, C, sporangiospores, D, zygospore (After Gilman)

Nineteen species are known, but only seven, including the synonyms, have been reported from India.

KEY TO THE COMMON SPECIES

1 Spores elongate cylindric, appendages on only one of the suspensors
  2 Spores 4–5 μ long . . . 1. *A. spinosa*
  bb Spores 6–11 μ long . . . 2. *A. heterospora*
aa Spores oval or globose, appendages, where known, on both suspensors
  2 Columellae furnished with a single, terminal prolongation
    c Prolongation of columella short, pointed, columella globose, mammiform . . . 3 *A glauca*
    cc. Prolongation longer, rounded at tip columella turbinate
    4 Spores globose, 2 5–3 6 μ in diamter . . . 4 *A orchidis*
      d Spores globose, larger 4–5μ.
        e Sporangia erect . . . 5 *A. coerulea*
        ee Sporangia nodding . . . 6 *A reflexa*
  bb Columellae smooth or rarely faintly spinescent
    c Spores generally globose, rarely oval, 3–4 μ in diameter, columellae generally spinescent
      d Strong growth at 37°C . . . 7. *A. lichthemii*
      dd No growth at 37°C . . . 8. *A. repens*
    cc Spores regular, columellae smooth . . . 9. *A. butleri*

Absidia spinosa Lendner

Bull Herb. Boissier (Ser. 2), 7, 1907

Syn *Absidia cylindrospora* Hagem, *Math-naturw. Bl* 7 1, 1907.

Tieghemella spinosa Lendner, *op. cit* 7. 1, 1907.

Turf very close, producing grayish cottony mat, about 2.5 cm above the sbu-

stratum Stolons slightly curved, arched, carrying sporangia in groups of two or three Sporangia pyriform, terminal, length from apophysis to sporangium 34 μ, width 28 μ Columellae 20 μ wide, swollen, ending in a blunt or rounded spine reaching $\frac{1}{3}$ the length of the columella (or $\frac{1}{2}$ the length in the Indian isolate) Septa present, 25 μ below the apophyses, separating the sporangia from sporangiophores Spores hyaline, oval, or rod like Occasionally slightly constricted in the middle, 4–5 μ long, 2 μ in diameter Zygospores spherical, verrucose Gametangia unequal on forked hyphae with circinate appendages on larger suspensor

Saksena's (1954) description differs slightly from the original, and according to him the turf on the malt agar was at first white, arched, carrying the sporangia in groups of 2-5, sometimes singly Sporangiophores unbranched, length variable, up to 180 μ Sporangia pyriform, terminal, brownish, 25-35 μ long, septate, and up to 25 μ wide Columella conical, 15–20 μ wide, swollen, ending in a well-formed spine, the spine reaching one-third the length of the columella Septa present, 20–25 μ below the apophyses Spores ovoid, elongated or cylindrical, hyaline, sometimes slightly constricted in the middle, 4–5 $\mu \times$ 2–2 5 μ Zygospores not observed

Absidia fusca Linnemann (1935) is closely related, if not identical, to the above species It is also reported from soil in Austria, Canada, Denmark, Egypt, France, Germany, Greenland, Morocco, Norway, Switzerland, the U S A and the U S S R

HABITAT On soil (Saksena, S B 1954, Ramakrishnan, 1953)

DISTRIBUTION · India (Saugar, Madras), Austria, Canada, Denmark, Egypt, England, France, Germany, Greenland, Morocco, Norway, Switzerland, U S A and U S S R

Absidia heterospora Ling-young

Rev. gen. Bot. 42 . 739, 1930.

Turf thick, dark gray, 5–10 mm high Stolons elongate, with thin rhizoids Sporangiophores at first hyaline, later violet and dark-gray, occurring in twos and threes, 0 2–0 5 mm long but average length of Indian form is 0 5 mm, 10 μ thick, with a cross-wall below the sporangium Sporangia at first yellow, then greenish-brown, 30–50 μ broad, with diffluent wall Columellae hemispherical, 25–30 μ broad Spores hyaline, cylindric, constricted in the middle, slightly orange-tinted, 2 5–6 μ broad and 6–11 μ long Gemmae and zoospores absent

Absidia glauca Hagem

Math-naturw Bl 7 . 1, 1907
Syn. *Tieghemella glauca* Hagem, *op cit* 7 1, 1907

Cultures gray-green, but turn clear yellow-brown at later stages. Branching of stolons similar to that of *A orchidis* Fertile branches single or in groups of 2–4 Sporangia pyriform, measuring 40–50 μ in diameter, 44–60 μ in length Septum divides pedicel from the sporangium Wall incrusted with granules, diffluent and leaves a straight collarette Columella rounded, breast-shaped (mammiform), with a very short button, 30 μ in diameter, 38 μ in length Spores round, hyaline, 3–3 5 μ

HABITAT: In ponds (Bhattacharya and Bamah, 1953); on soil.

DISTRIBUTION: India (Gauhati), Austria, Canada, Czechoslovakia, England, France, Norway, Switzerland, U S.A., U.S S.R.

Absidia coerulea Bainer

Bull. Soc. bot. Fr. 36: 184, 1889.

Colonies at first white, later becoming blue-voilet in colour, 1-1.5 cm high, dense. Mycelium 5 6–16 8 μ thick. Sporangiophores single, borne directly on the thallus, unbranched, 25 mm long. Sporangia spherical, 36–42 μ, bluish-brown, with a septum generally 12–24 μ (in Indian specimen), 11 4–15 μ below the sporangium; membrane of the sporangium smooth, diffluent, leaving a collarette. Columellae hemispherical, pyriform, with a distinct papilla at the tip. Spores many, small, globose, 5.6–8 4 μ. Zygospores 60 μ brown, globose, rugose verrucose, not seen in Indian form. Grows well on potato-dextrose agar between 26°C and 37°C

A. coerulea can use ammonium nitrogen

HABITAT: Raizada (1957) isolated it from the Botany Department, Allahabad University; on soil (Holland).

DISTRIBUTION: India (Allahabad), Holland.

Absidia lichtheimii (Lucet et Const.) Lendner

Bull Soc. mycol. Fr. 19:106, 1903.

Lichtheimia corymbifera Vuill. *Bull. Soc. mycol. Fr.* 19: 1066, 1903.

Sporangiophores prostrate, branched in corymbs, forming white woolly felt, terminating the corymbiform branching, bearing sporangia on longer or shorter pedicels. Frequently, groups of branches carrying smaller sporangia occur below the terminal corymb. Sporangia erect, hyaline, pear-shapėd, with infundibuliform apophyses, becoming attenuate gradually to sporangiophore, average diameter 45–60 μ, largest 70 μ and smallest 10–20 μ. Wall of sporangium colourless, transparent, smooth, diffluent, leaving a basal collarette. Rugmini (1956) found sympodial branching as against the corymbose of the type species; the average size of the sporangia smaller, being 28-50 μ, against 45 to 60 μ of the type spacies; the growth on malt agar (where turf is 1–1 5 cm in height) woolly, the aerial hyphae repeatedly and irregularly branched, 5–9 μ wide, with arching stolons and rhizoids. Sporangiophores erect, at first simple, but later branch profusely; branching opposite or unilateral with a septum below the sporangium. Columellae large, hemispherical or globular, 10–20 μ, smooth, or rarely with short spines, smoky-gray or brown, apophysis and pedicel also similarly coloured. Spores spherical, subspherical or rarely oval, brown, 2 5–3.5 μ in diameter. They have also been reported to be colourless, 2 μ in diameter and 3 μ or sometimes 4–6.5 μ long. Chlamydospores and zygospores not found.

HABITAT: On soil (Rugmini, 1956).

DISTRIBUTION: India (Saugar); Czechoslovakia (Niethammer, 1935); Egypt (Sabet, 1935); U.S.A. (Waksman, 1916), and China (Kominami *et al.*, 1953).

Absidia butleri Lendner

Bull Soc bot. Genéve 18 · 1926
Syn *Absidia subpoculata* Paine, *Mycologia* 19 248, 1927

Colonies white floccose, aerial hyphae growing to a height of 1 5–2 cm; stolons branched, with sporangiophores, both occurring in groups of 1–5, sporangiophores branched, 100–300 μ long, 4 μ in diameter, with a smooth diffluent wall, leaving a slight collarette Columellae oval, slightly constricted at the apophyses, with apophyses 10–20 $\times$ 7 5–15 μ, and without apophysis 4–7 $\times$ 8–9 μ, each apophysis rounded below into a distinct pouch. Spores oval to spherical to allantoid, 2–2 5 $\times$ 3 4 μ Chlamydospores numerous, spherical, 4–5 μ in diameter. Saksena's culture on Czapek's agar developed thick, white turf, 3–5 mm high, forming a velvety mat The length of the sporangiophor s varied up to 100 μ Septa present, usually about 12–18 μ, below the apophyses. Sporangia globose, 10–15 μ in diameter Columella hemispheric, 6–8 μ in diameter Apophyses very prominent, forming a distinct pouch-like structure, 4 6 $\times$ 5 7 μ. Numerous terminal or intercalary chlamydospores from submerged hyphae.

HABITAT: On forest soil (Saksena, S B , 1954, Shetye, 1954)
DISTRIBUTION: India (Saugar), U S A (Paine, 1927, Gilman and Abbott, 1927; Morrow, 1931).

Absidia blakesleana Lendner

Bull. Soc. bot. Genéve 15 : 147, 1963.
Syn. *Protoabsidia blakesleana* (Lendner) Noumov , *Clés des Mucorinées*, 1939.

Colonies low, 1–2 mm high, deep grayish, sporangiophores not septate, simple or with one single branch, vertical, with branches often bent back towards the bottom (as in *Circinella*) Apical sporangia 38–44 μ in diameter (laterals 18–24 μ) with diffluent wall. Columella elliptical with a spine at the top, with an ashy-blue memberane, 20–24μ in diameter. Spores irregularly spherical or in wide ellipse, colourless or grayish blue, (4–) 5–6 (–7–8) μ in diameter Zygotes spherical, with a light-brown wall 50–60 (–70) μ, covered with lamellae, which are in the form of thickenings, indistinctly prominent Zygospores without appendix Heterothallic

HABITAT: In surface washing of *Nephelium litchi* from Calcutta (Saha, 1945)
DISTRIBUTION: Calcutta

Absidia regnieri Lucet et Const

Rev. gén Bot 12 : 1900
Syn. *Mucor regenieri* Sacc , *Syll fung*. 20, 1908
Tieghemella glauca Hagem , *Math-naturw Bl* 7, 1907.
T tieghemii (Deckenbach) Naumov (*cf Clés des Mucorinées*, 1939).
Absidia glauca Hagem, *Math-naturw Bl* 7, 1907
Litchtheimia regieri (Lucet et Const) Vuillemin, *Ann Mycol* 1 · 420, 1903

The fungus has failed to react with plus (+) and minus (—) testers, therefore, its sex could not be determined by them

For general description refer to *Absidia glauca*

HABITAT : On dung of camel (Ajrekar and Rajulu, 1931), on shoes (Reese *et al*, 1950—as *Mucor regieri*)

DISTRIBUTION : Bombay.

Genus **RHIZOPUS** Ehrenberg

Nova Acta Acad. Leop 10 : 198, 1820; ex Corda,
Icon Fung. 2: 20, 1838
Syn *Ascophora* Tode ex Fries 1790, *Syst Mycol* 3 : 309, 1832
Philophora Wallroth, *Flora Kryptog Germ* 4 : 332, 1933

Aerial arching stolons developed from the nutritive mycelium as in *Absidia*, forming a tuft of repeatedly branched rhizoids (Fig 25) at the point of contact with the substratum, sporangiophores arising from the stolons exactly opposite the point of origin of the rhizoids, usually unbranched and fasciculate, sporangia terminal, large, globose, many-spored; columella prominent, more or less hemispherical, sporangial wall not cutinized almost wholly disappearing at maturity, sporangiospores globose to oval or angular, smooth or marked by longitudinal striations, rarely echinulate, zygospores formed from nutritive mycelium or from stolons, suspensors without outgrowths. *Circa* 30 species are known, but only six of them have been reported from India.

KEY TO THE SPECIES

1. Aerial sterile mycelium absent, well-marked difference in stolons, sporangiophores and rhizoids, lateral sporangiophores absent	
1a. Species heterothallic	*R nigricans*
1b. Species homothallic	*R. artocarpi*
2. Aerial sterile mycelium present, difference in sporangiophores, stolons and rhizoids less marked, very frequent formation of lateral sporangiophores	
2a Sporangia small (about 100 μ in diam)	*R combodia*
2b Sporangia very big	
2b (i) Sporangiophores without swellings	
2b (i) (A) Spores 5–7 μ long, columella 40–75 μ high	*R arrhizus*
2b (i) (B) Spores 7–8 μ long; columella 82–110 μ high	*R. oryzae*
2b.x(ii) Sporangiophores with swellings, spores absent	*R nodosus*

Rhizopus nigricans Ehrenb.

Nova Acta Acad. Leop. 10 . 198, 1820.
Syn. *Mucor stolonifer* Ehrenb , *Sylvae Mycol. Berol*, 1818
Rhizopus stolonifer Lind , *Danish Fungi*, p 72, 1913
R artocarpi (Raciborski) Lendner, in *Kryptogamenfl Scheweiz*. 3 : 1-18, 1908 (as a form).

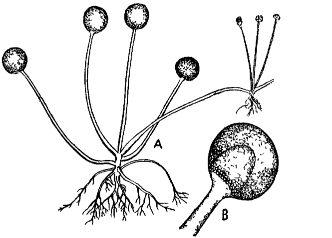


FIG 26 *Rhizopus nigricans* Ehrenb A, fascicle of sporangiophores arising opposite the rhizoids and connected by a stolon with another group, B, enlarged sporangium showing columella and spores (After Atkinson, 1908)

Stolons creeping, recurving to the substrate in the form of arachnoid hyphae, which are raised up from the substrate and implanted at the nodes by stout rhizoids Internodes extend up to 1–2 or even 3 cm Sporangiophores usually in groups of 3–10, sometimes only 3–5 (Rugmini, 1956), 0 5–4 mm in height and 24–42 μ in diameter, sometimes 1–2 mm high and 16–20 μ in diameter (Rugmini, 1956) Apophysis broad, cuneiform, sporangia globose or hemispherical, 100–300 μ in diameter, granular, olivaceous Columella prominent, hemispherical, 90 μ in height and about 70 μ in diameter, maximum size 250 × 320 μ Average diameter of Indian specimen 100 μ Spores in chains, irregularly round or oval, angular, striate, grayish, 14 × 11 μ (5–7 × 3 5–4 0 μ in the Saugar specimen) Zygospore round, 160–220 μ in diameter but average diameter of Indian form 220 μ, exine brown-black, verrucose Suspensor swollen, usually unequal, absent in the Saugar specimen Azygospores common, chlamydospores absent

HABITAT In soil, on rotting fruits, seeds and other parts of plants, on field beans Rajan *et al* (1952) reported it (as *R stolonifer*) from atmosphere at Kanpur

DISTRIBUTION Cosmopolitan Madras, Punjab, Bengal, Saugar Austria, Canada, Denmark, Egypt, England, France, Germany, Italy, Japan, Norway, Switzerland, U S S R and U S A

R. nigricans is a very common fungus and has been found in various localities

Though it is generally considered saprophytic and may occur inside the shells of walnuts, rotten chestnuts or even on the walls of rooms, it is also responsible for numerous diseases and causes considerable economic loss. It has been reported from practically every country and is known to damage maize, beans, soya beans, castor beans, seeds of various cereals, stone fruits, flax, cigarettes, etc It causes boll rot of cotton, rotting of groundnuts, grapes, pine-apples, oranges, apples, rutabaga, tomato, carrot, fig, cherries, and peaches, and is responsible for serious losses to sugar-beet, papaya (watery rot), strawberry (leak), flex, meat and citrus (internal rot). It may damage young maize seedlings, develop seedling blight of *Sorghum*, or kill beet seedlings It is responsible for a soft rot of *Helianthus tuberosus* and a dry rot of *Helianthus annuus*. Due to this organism the roots of horse-raddish may get water-logged It develops a secondary rot of bananas In India, very little work has been done on the pathogenic aspect of this fungus, and it appears necessary that a more careful study is undertaken.

Harter and Weimer (1923) reported physiologic specialization in this fungus. It has also been observed that the mycelium of the + strain can grow even after five years or more but the — strain cannot survive under similar conditions. Generally, the survival is due to spores and not to mycelium. According to McCrea (1923), its spores can survive for 22 years in sealed tubes It has been shown by Le Clerg and Smith (1928) that low soil moisture favoured its growth. Heintzeler (1939), however, found that it required 80 to 90 per cent humidity for its normal growth According to Harison (1934) its optimum temperature is 30°C, while Scheffer (1930) found that an exposure of five minutes to steam destroyed it.

Ronsdorf (1935) reported that it produced minute quantities of auxins. Vasudeva and Govindaswami (1953) established that its filtrate checked the growth of *Fusarium udum* Brown and Harvey (1927) observed that its germ tubes could penetrate various membranes. It is capable of producing pectinase (Scaramella, 1931).

Rose (1924) obseved that the critical temperature of the peach rot caused by this organism was 50°F. Kobs and Robbins (1936) found that acid dyes were toxic to it, while Brooks *et al.* (1934) established that CO_2 prevented rot of fruits and vegetables, and on this basis they have suggested methods for the control of some diseases caused by this fungus. It has been observed that concentration of 30 per cent CO_2 inhibited germination of its spores; that CO_2 gets accumulated both under aerobic and anaerobic conditions during its growth (Foster *et al.*, 1941); that lactose and sucrose were poor sources of carbon for it (Margolin, 1941); that zinc was essential for the development of its zygospores (Neithammer, 1939), that the organism was self sufficient in thiamin (Robbins and Kavanagh, 1942); that the + strain produced abundance of fumaric acid, while the — strain failed to do so (Foster and Waksman, 1939); and that utra-violet radiations had lethal effect on its growth (Fulton and Coblentz, 1929).

R. nigricans Ehrenb. var. **minutus** Chaudhuri

Proc. Indian Acad. Sci. B 2: 137-54, 1935.

Syn. *R. nigricans* Ehrenb. var. *minor* Jensen, *Bull. agric. Ex. Sta. Cornell* 315 : 447, 1912.

Colony white to begin with, then turning black, growth cobwebby, turf 2 cm high, stolons far-spreading, internodes at first hyaline, finally turning brown, branched rhizoids given off at nodes, at first colourless then turning brown, smooth thick membrane, about 7 2 μ thick and getting thinner towards the tip, sporangiophores mostly in clusters of 3–5, rarely single, unbranched, about 900 μ high and 17 μ thick, with smooth (finally) brown membrane, sporangia almost round, average diameter 200 μ, at first snow-white, becoming black at maturity, columella globose, broader at the base, with brown, smooth membrane, often covered with spores after opening of sporangia, very often also becoming pileate, spores irregularly globose or broad-oval, mostly with one or two blunt corners, 5 4–6 5 μ in diameter, with thick double membrane, pale-gray in colour.

This variety is very near *R nigricans* Ehrenb , and differs from it mainly in having shorter sporangiophores and much smaller spores

HABITAT: On soil (Chaudhuri and Sachar, 1934, Chaudhuri and Kochhar, 1935, Roy, 1948; Bhattacharya and Baruah, 1953)

DISTRIBUTION: India (Punjab, Chinsura, Gauhati), U S A (Illinois), England

Rhizopus arrhizus Fischer

Rabenhort's Kryptogamenfl 1 abstr. 4, 1892

Zycha (1935) recognized *R arrhizus* as a synonym of *R nodosus* Namys, but the two species are considered distinctly here

It occurs in soil as well as on rotting fruits Sinha (1943) isolated this from stored fruits of mango, apple, pear, peach, pomegranate, orange and grapes Mehta (1937) found that it caused a soft rot of apples while Padwick (1939) observed that it caused a decay of apples It differs from *R nigricans* by its less exuberance

Felt clearer and not extending far into the substrate. Stolons little developed, not forming nodes regularly. Rhizoids pale, developed at nodes bearing sporangia, or sometimes formed indeterminately. Sporangiophores often prostrate, rarely single, forming umbels or corymbs on their stolons, measuring 0 5–2 mm in length All branches ending in sporangia Sporangia spherical, 120–250 μ in diameter, columella spherical, flattened on the apophyses, 40–75 μ high, 60–100 μ in width, membrane brown, smooth Spores round or oval or with obtuse angles, grayish-brown, wall striated longitudinally, 4 8–7 × 4 8–5 6 μ Rarely, sporangia are globose and 200–3000 μ in diameter. In early stages snow-white, at maturity black Columella spherical 90–160 μ in diameter with brown, smooth membrane (Chaudhuri and Sachar, 1934) Fungus capable of synthesizing lactic acid.

HABITAT: On soil and rotting fruits (Mehta, 1937, Padwick, 1939, Sinha, 1943)

DISTRIBUTION: India (Punjab, Uttar Pradesh, Pusa, Delhi), Czechoslovakia, Egypt, England, Germany, Hungary, Panama, U S A

Scharff and Catanei (1944) reported it from humus in Algeria, and Ciferri (1927)

from cocoa It has been found to stain dyed cotton (Hardy, 1942), to attack rubber extract in Philadelphia (Allen *et al*, 1944); to cause rot of tobacco in Rhodesia (Hopkins, 1938), and to cause a carbonaceous rot of cotton seed (Roger, 1939)

Rhizopus nodosus Namyslowski

Bull Acad Sci. Cracovie 1906

Syn *Rhizopus arrhizus* Fischer, *Kryptogamenfl Mark Branderber* 1: 161-310, 1892.

Mycelium cottony white when young, turning later to ochre-yellow. Branches ending in sporangia, occur in midst of mycelium and on stolons Such branches are 1–2 mm in height, 12–28 μ in diameter; wall thick and smooth, colourless at first, later turning pale ochre or brown, simple or branched; branches may be swollen at any point, and end in sporangia Terminal swellings form groups of 3–5 sporangiophores each terminating in a sporangium. Sporangiophores 1–2 mm in height. Sporangia globose, 100–200 μ in diameter Spores longitudinally striate, 6–9 μ long, 46 μ wide, chlamydospores, when present, 16–32 μ in diameter Zygospores round, oval or without definite shape, 120–140 μ in diameter. Suspensors equal or different in size and shape Saksena, S B (1955) records branches about 1 mm in height, 10–20 μ in diameter, sporangiophores 1–1.5 mm in height, 10–15 μ in diameter, diameter of sporangia varying from 75 to 120 μ, columella dome-shaped, about 50 μ in diameter; spores slightly smaller, 5–8 × 3–4 μ. Zygospores not observed

HABITAT: On soil (Hukum Chand, 1937; Bhattacharya and Baruah, 1953); on cotton seed (Venkataram 1950)

DISTRIBUTION : Pakistan (Lahore), India (Saugar, Madras, Assam), Austria, Czechoslovakia, France, Denmark, Norway, Switzerland.

Rhizopus artocarpi Raciborski

Parasit Algen Pilze Javas 1: 1900.

Mycelium dense, white, floccose, developing a thick mat (on the fruit); turf at first white, later turning black, forming a layer 2–3 mm in thickness; stolons creeping and recurving to the substrate, implanted at each node by a group of rhizoids; internodes long Sporangiophores brown, unbranched, arising in groups of 3–5, typically opposite the rhizoids, very long, 1–1 5 mm, and 21–35 μ, in width Sporangia globose to hemispherical, large, 170–190 μ in diameter (140–210 μ, Rugmini, 1956) Sporangia wavy, diffluent, leaving a basal collarette. Apophysis broad Columella ovate to hemispheric, 80–100 μ (75–90 μ, Rugmini, 1956) with various shapes—angular, spherical, oval or irregular—12–16 μ long, the spherical ones 6 3 μ in diameter. Sometimes spores slightly smaller, 5.6–8 × 9 8–12 μ (Rugmini, 1956). Zygotes 96–190 × 66–105 μ. Homothallic.

HABITAT : On inflorescence and fruits of *Artocarpus integrifolia*.

DISTRIBUTION: India (Banaras, Allahabad, Assam, Saugar), Andamans, Fiji (Parham, 1942), Hawai (Petrak, 1953), Philippines (Crisunto, 1924).

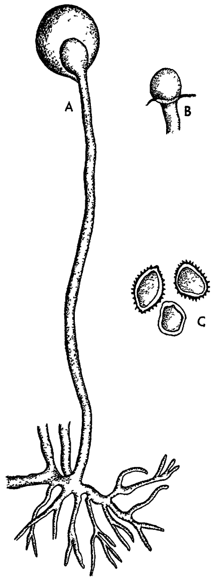
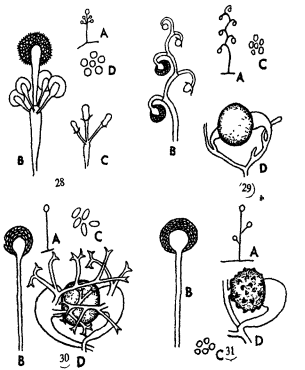


FIG 27. *Rhizopus artocarpi* Raciborski A, rhizoids and sporangium, B, ruptured sporangium, C, spores (After Rugmini, 1955)



[FIG. 28. *Actinomucor*. A, habit B–C, sporangiophores, D, sporangiospores (After Gilman).
FIG. 29. *Circinella*. A, habit; B, sporangiophore; C, sporangiospores; D, zygospores (After Zycha).
FIG. 30. *Phycomyces* A, habit; B, sporangiophores; C, sporangiospores; D, zygospore (After Gilman).
FIG 31. *Zygorhynchus*. A, habit, B, sporangiophore; C, sprangiospores, D, zygospore (After Gilman).

Rhizopus combodia Vuillemin

Rev. Mycol. 24 : 45, 1902.

Mycelium white, turning grayish-blue with age, 10–12 mm long, runner-like, 3–14 μ in diameter, and 120 μ to 8 mm long; contents yellowish; rhizophores generally few, branched, hyaline, then brown, 3–7 μ, occasionally septate, fertile hyphae 100—1000 μ long and 7.2–14 μ broad, erect or curved, brown, commonly simple, rarely branched; sporangia globose, 50–100 μ in diameter, gray or brown in early stage but mature ones blue or black with fragile wall, columella 22–44 $\times$ 25–44 μ, hemispherical or globose with brown outlines; spores light blue, oblong or globose, 4 5 $\times$ 3.7–5 2 μ. Zygospores not observed.

HABITAT On fermenting rice (Hutchinson and Ram Ayyar, 1915)
DISTRIBUTION India and Canada

Rhizopus oryzae Went et Gerlings

Verh Akad Wet Amst 4, 1895

Colonies 1–3 cm high, remaining whitish, aerial sterile mycelim present, rhizoids brown-yellow, unbranched (or very little branched), sporangiophores not quite straight, often branched with swellings Sporangia 115–150 μ, columella spherical or cylindrical, 82–110 (–125) μ in diameter spores variable in form, most often irregular, slightly angular, striate, of 4 2–7 8 μ in diameter or 5 4–10 8 × 4 2–8 4 μ, light gray or brown.

HABITAT· Isolated from tobacco field soil (Zachariah, 1949, Subramanian, 1952)
DISTRIBUTION. India (Coimbatore)

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Genus ACTINOMUCOR Schotakowitsch

Ber. dtsch. bot Ges 16 155-158, 1988

Syn *Glomerula* Bainier, *Bull Soc mycol Fr* 19 153-172, 1903

Mycelium branched; stolons and rhizoids present, but branched; sporangiophores typically (but not always) arising oppsoite rhizoids, branched, septate, often bearing below a terminal sporangium a whorl of short branches which are often thickened and which terminate in small sporangia; all sporangia spherical and many spored; apophysis lacking; sporangiophores continuous, hyaline, and never striate, zygospores unknown, chlamydospores present or absent

Actinomucor is a monotypic genus, originally described from Siberia by Schostakowitsch in 1898. It differs from *Mucor* in having branched stolons which give rise to rhizoids and sporangiophores, and from *Rhizopus* and *Absidia*, the two other stoloniferous genera, by the limited growth of its stolons and different formation of its columellae and sporangiophores (*see also* Benjamin and Hesseltine, 1957) It differs, further, from *Rhizopus* in the projection of whorls of short branches below the terminal sporangia of the sporangiophores It also lacks dark pigmentation of the striated sporangiophores which characterize many species of *Rhizopus* Contrary to *Absidia* and *Rhizopus*, there is no apophysis in this genus It was placed in Thamnidiaceae by Lendner (1908) but Naumov (1939) and Zycha (1935) placed it in Mucoraceae, which is now generally accepted It is possible that like *Rhizopus* it has evolved from an ancestor of some member of Sphaerosporus section of *Mucor*.

Actinomucor repens Schost

Ber dtsch. bot. Ges 16 : 155-158, 1898

Syn *Actinomucor elegans* (Eidam) Comb. Nov Hessel, *Mycologia* 49 : 240-249, 1957.

Mucor corymbosus Harz, *Bull Soc Imp des Nat de Moscou* 44 : 143, 1871.

Rhizopus elegans Eidam, *Jber schles Ges vaterl Kult* 61 · 232, 1884

Mucor harzii Berl et de Toni, *Syll fung* 7 : 202, 1888.
Glomerula repens Eainier, *Bull. Soc mycol Fr* 19 154, 1903
Mucor glomerula Lendner, *Matér Fl Crypt Suisse* 1 . 69, 1908
M botryoides Lendner, *Bull Soc Bot Genéve* 2 · 79, 1901
M repens Bainier, Sacc et Trott, *Syll fung* 21 · 821, 1912.
M botryoides var *minor* Jensen, *Bull. agric Exp Sta. Cornell* 315: 447, 1912
M cunninghamelloides Pispek, *Acta bot*, *Zagreb* 4. 89, 1929
Actinomucor corymbosus (Harz) Naumov, *Clés des Mucorinées* Hukum Chand (1937) reported it from India as *M botryoides*

Stolons a few centimeters long, 10–15 μ thick, sporangiophores erect with variable length, much branched, each erect branch terminated by a very large sporangium below which occurs a whorl of 3–8 secondary filaments, each terminated by a sporangiole Sporangia spherical, hyaline, changing to senna colour when old, principal sporangia 120–180 μ in diameter, the lateral up to 30–45 μ, wall roughened due to presence of calcium oxalate crystals, diffluent, leaving a collarette, columella variable in shape, hemispheric, cylindroconic, ovoid, sometimes restricted, inserted at the abruptly expanded end of the sporangiophore Spores spherical, uniform and smooth, average diameter 7 μ, aerial chlamydospores round, with thick, yellow, spiny wall Mycelial chlamydospores seemingly submerged but numerous, 20–35 × 5–15 μ Zygospores absent

HABITAT: Soil

DISTRIBUTION: India (as *Mucor botryoides* Lendner by Hukum Chand, 1937, from soils of Lahore); U S S R

Genus **CIRCINELLA** van Tieghem et le Monnier

Ann Sci. nat. A (ser 5) 17 . 261-239, 1873

Syn *Circinumbella* van Tieghem et le Monnier, *C R Acad Sci Paris* 74 : 999, 1872

Mycelium hyaline or coloured Sporangiophores branched sympodially, indefinite in length, branches with one or many sporangia, occasionally with a sterile spine Sporangia always borne circinately at the end of the branches, spherical or globose with a persistent and incrusted sporangial wall (except in terminal sporangia of *C linderi*), many-spored, sporangiola absent, columellae variously shaped, always with a well-defined collar, sporangiophores usually spherical or globose, smooth, zygospores produced between equal and unadorned suspensors, nearly smooth-walled

Eight to nine species are known, but only two have been reported from India

KEY TO THE INDIAN SPECIES

1. Sporangiophores not twisted, with spines, sporangia almost always together on the same branch — *C spinosa*
2. Sporangiophores always angled, irregular in shape — *C simplex*

Circinella simplex van Tieghem

Ann Sci nat A 1 : 92, 1875

Syn *Mucor simplex* (van Tieghem) Migula, *Kryptogamenfl* 5 *Deutschl Gera* 3 194, 1910

The turf on malt agar at 26°C very short, at first white, but later turning to brown or brownish black, 0 5–3 0 mm in height (Rugmini, 1956) Sporangiophores erect, 2–3 mm high, richly branched, bearing sporangia on alternate lateral branches, leaving a sterile basal portion of about 0 5 mm Sporangia with curved, unbranched pedicels, very small, spherical, 40–50 μ in diameter, non-septate, wall cuticularized, brownish black, persistent, breaking into pieces, incrusted with oxalate and leaving a basal collarette Columellae concrescent at the base, cylindrical-conical in the type specimen, but spherical to sub-spherical in Rugmini's culture Spores minute, hyaline, spherical smooth, 3 μ in diameter, sometimes 3–4 μ (Rugmini, *loc cit*), wall double-layered

The slight difference between the type and Rugmini's specimen appears to be connected with the medium on which the latter cultured it

HABITAT On dung of goat, rabbit and lizard (Rugmini, 1956), soil

DISTRIBUTION India, Brazil, U S A

Circinella spinosa van Tieghem et le Monnier

Ann Sci nat A 17 261-399, 1873

Syn *Mucor spinulosus* Schro *Kryptogamenfl* V *Schlesien* (Cohn) 1 1866

Circinella muscae (Sorokine) Berl et de Toni *Syll fung* 7 1, 1888

Basynym · *Helicostylum muscae* Sorokine, *Bull Soc Imp Nat Muscov* 43 256, 1870

Primarily, hyphae erect and bent upwards, branch from an angle; branches almost equal to the primary hyphae, only slightly branched at the apex, apex somewhat acute, often septate and laterally hanging Sporangiophores slender, erect, close and climbing, mutually sustaining one another forming a turf 2 cm high, top of the sporangiophore sterile, or rarely bears a sporangium, diameter of terminal sporangium 147 μ, lateral sporangia in two series along the primary sporangiophore, below on curved pedicels which are prolonged into a hypha in the form of a spine, and above the pedicel without spines Sporangia circinate The outermost branch circinate, bearing the sporangia which are small, globose, incurved, 60 μ in diameter, brown, echinulate, cuticularized and incrusted with colourless contents, separated by a wall at the base of the filament Columella cylindrical or cone-shaped, and may be slightly constricted Spores spherical, slightly blue and smooth, 4 μ in diameter Zygospores absent

HABITAT. On dung of zebra, buffalo and camel (Ajrekar and Rajulu, 1931), cocoa beans

DISTRIBUTION· India, Philippines

Genus **PHYCOMYCES** Kunze

Mycol Hefte 2 113, 1823

Mycelium wide-spreading, in and on the substratum, richly branched, stolons

absent; sporangiophores simple, stiffy, erect, possessing a pronounced metallic irridescence, often exceptionally tall, in some cases reaching a length of 25–30 cm, but generally much shorter. Sporangia terminal, large, globose with a pyriform apically broadened columella; sporangial wall uncutinized, somewhat incrusted with crystals of calcium oxalate, soon disintegrating; sporangiospores smooth, yellowish, ellipsoidal. Zygospores formed on the mycelium; copulating branches shaped like tongs and forming the zygospore between their tips; suspensors provided with dichotomously branched, dark-brown, rigid outgrowths, radiating in various directions and appearing like antlers (Fig. 30), not enclosing the zygospores as in *Absidia*

Burgeff (1925) experimentally produced the hybrid between two fungal species (*P. blakesleeanus* and *P. nitens*) belonging to this genus.

Four species are known; of these only one is reported from India

Phycomyces microsporus van Tieghem

Ann. Sci. nat. A. 1 : 5-175, 1875.

Colonies bright, white, dense, undeveloped sterile mycelium present. Sporangiophores straight, without branches, with a metallic lusture, 4–5 cm long sometimes 7–8 cm long (Raizada, 1957). Sporangia brownish, spherical, 80–105 μ in diameter. Columellae pyriform, $72.5 \times 45\ \mu$. Spores spherical 8 μ in diameter, sometimes 6.2–8.8 μ (Raizada, *loc. cit.*). Zygospores spherical, 125 μ in diameter.

P. microsporus grows well on P.D A. at 26°C. It is similar to the type, except in the size of sporangia.

HABITAT: Fresh mangoose dung (Raizada, 1957).
DISTRIBUTION: India (Allahabad).

Genus **ZYGORHYNCHUS** Vuillemin

Bull. Soc. mycol. Fr. 19: 116 1903.

Sporangial stage similar to that of *Mucor*; zygospores formed in a characteristic manner from wholly dissimilar gametangia (Fig. 31)

Lendner (1908) merged *Zygorhynchus* with *Mucor*, but most of the modern workers have not accepted this change and have retained the genus to include types with *Mucor*-like sporangia and dissimilar gametangia. All species are homothallic.

In the zygospore formation (Gruber, 1912; Atkinson, 1912; Blakeslee, 1913) the terminal portion of an erect hyphae is delimited by a septum from the part below, followed by the development of a lateral branch just beneath the septum. This branch grows upwards, and recurves to meet the side of the main hyphae above the septum; at the point of contact the main hypha pushes out and cuts off a small gametangium. The much enlarged tip of the lateral branch also cuts off a gametangium. The zygospore formed by their union is always homothallic in origin The terminal delimitation of the main hypha often turns to one side and projects beyond the zygospore as a slender prolongation, giving a characteristic appearance to the zygosporic apparatus.

Six to seven species are known, but Saksena and Mehrotra (1952) reported only

two from India (Allahabad), though the species have not been named. However, these may be separated on the following basis

1 Zygospores on much-branched suspensors, sporangia absent on Czapek's solution, Blakeslee's medium and oat-meal medium sp 1

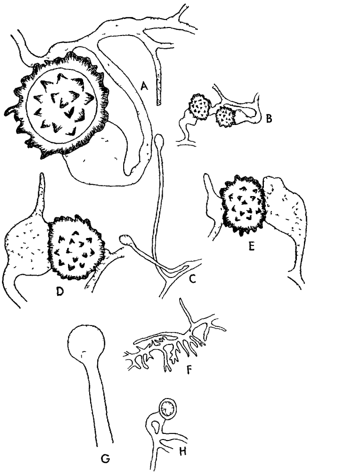


FIG 32 *Zygorhynchus* sp, Saksena and Mehrotra A–B, zygospores, C, D, E, *Zygorhynchus* sp 2 Saksena and Mehrotra C, two sporangia arising from a hypha, D–E, zygospores, F, G, H, *Zygorhynchus vuilleminii*, F, mycelium, G, sporangium with spores, H, chlamydospore (After Saksena and Mehrotra)

2 Zygospores formed on special mycelial filaments, sporangia present, ray, globose to cylindric, 40–45 × 28–30 μ sp 2

Zygorhynchus sp I

Fig 32 A, B

Hyphae continuous, branched, unequal, forming a cottony aerial turf about 10 mm high. Zygospores on much branched suspensors, 50–80 μ in diameter, brown with reticulate exine. Sporangia absent on Czapek's. Blakeslee's and oatmeal media

HABITAT: On soil.
DISTRIBUTION : India (Allahabad)

Zygorhynchus sp. II

Fig 32 C-E

Hyphae continuous, branched, forming a cottony, aerial, white to gray turf. Sporangiophores erect, rarely branched, each branch ending in a sporangium. Sporangia gray, globose to cylindric, $40–45 \times 28–30\mu$ Spores round 2–2 5μ in diameter, smooth, hyaline Gametangia unequal, one often a slender, the other thicker; rarely both are thicker, but remain unequal Zygospores formed on special mycelial filaments, branched sympodially. Zygospores variable in size, 40–60μ in diameter, brown; exine reticulate $(4 \times 2\mu)$

HABITAT: On soil.
DISTRIBUTION : India (Allahabad).

Zygorhynchus vuilleminii Namyslowski

Ann. Mycol 8: 152-155, 1910

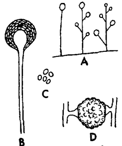
The following description is based on R K Saksena and Mehrotra's (1952) specimens grown on Czapek's oatmeal and glucose-peptone media

Turf white, sporangiophores 5-8μ broad, diffluent; sporangia globose, 30–45μ (up to 60–80μ) in diameter, terminal, larger, columella broader than high, ovoid, 12–30μ broad, maximum 35μ, spores hyaline, ellipsoid, $4 \times 2\mu$ often guttulate; chlamydospores smooth, oval or elongate, and of various sizes Zygospores and azygospores not observed. They have been described on type specimen. (when present) globose; exine verrucose, brown, 40–50μ in diameter, azygospores occasionally present.

Saksena (R K) and Mehrotra (*loc cit*) consider the two species described earlier identical with *Z vuilleminii* The latter can be distinguished from *Z moelleri* by the exine having much smaller warts, commonly aggregated

HABITAT· On soil.

DISTRIBUTION India (Allahabad), Canada, Germany, Yugoslavia, U S S R, and U S A



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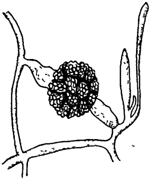

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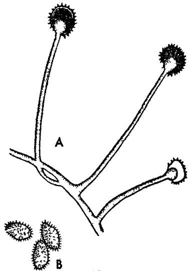

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FIG 33 *Mucor* A, habit, B, sporangiophore, C, sporangiospore, D, zygospore (After Gilman)
FIG 35 *Mucor hiemalis* Wehm Mature zygospore (After Rugmini, 1955)
FIG 36 *Mucor saturninus* Hagem A, sporangiophores, sporangium and columella, B, spores (After Rugmini, 1955)

Genus **MUCOR** Micheli

Syst. Myc. 3: 1842.

Syn *Ascophora* Tode, *Fungi, Mechlenb sel* 1 . 13, 1974
Hydrophora Tode *op. cit.* 2 : 5, 1971
Chionyphe Theinemann, *Nova Acta Acad Leop* 19. 19, 1839.
Calyptromyces Karsten, *Bot. Zeit* 7 365 1849
Pleurocystis Bonorden, *Handb. Allge-Mycel* 124, 1851.
Scitovszkya Schulzer, *Verh. zool.-bot Ges* 16 36, 1866.

Chlamydomucor Brefeld, *Unters Gesam Mykol* 8. 223, 1889.
Amylomyces Calmette, *Ann Inst Pasteur* 6 611, 1892.
Ascidophora Reich, *Syll. fung.* 15 48, 1901.
Zygorhynchus Vuillemin Lendner, *Mater. Fl crypt. Suisse III*, 1, 1-177, 1908.

Mycelium developed profusely both in and on the substratum, lacking definite rhizoids and stolons; sporangiophores not fasciculate as in *Rhizopus*, arising singly from the mycelium, erect, simple or somewhat branched in a monopodial or sympodial manner, all the branches terminated by sporangia; sporangia large, globose, many spored, sporangial wall evanescent in most species, not cutinized, more or less incrusted with crystals of calcium oxalate; columella always present, various in shape; sporangiospores globose to ellipsoidal, wall thin, smooth; zygospores borne on mycelium, suspensors lacking outgrowths; copulating branches lying end to end and forming a straight line, terminal or smooth, hyaline, chlamydospores formed in some species

Lendner (1908) used the occurrence of branching of sporangiophores, their height and thickness, the diameter of the sporangium, the length and thickness of the columella, the dimensions of the spores, the degree of diffluence of sporangial membrane,

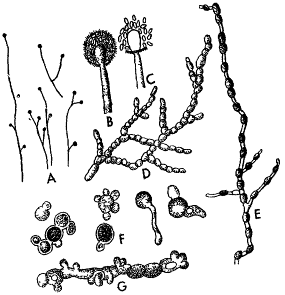


FIG 34 *Mucor racemosus* Pres A, sporangiophores, B, sporangium, C, opening sporangium with columella and collar, D, yeast-like cells, E, hyphae with gemmae; F, sprouting cells; G, young hyphae forming oidia with sprouting cells (After Brefeld)

and the form of columella and shape of the spores for the classification of *Mucor* The characters of zygospores were not taken into consideration as they were rare On the basis of branching he subdivided the genus into three sections, viz, Monomucor, Recemomucor and Cymomucor Many of the above characters are liable to considerable variation even in a single individual and cannot be relied upon much The occurrence of branching of the sporangiophores is the most important single character but it is difficult to determine this in many cultures because of the close intermining of the hyphae Observations at the edge of the colony are unreliable as developing sporangiophores are unbranched

Naumov (1939) has divided it into thirteen sections, viz, Micromucor, Circinellastrum, Lendnerella, Heteropus, Bonordenia, Hagemia, Byssomucor, Fischerella, Macromucor, Thamnidioides, Piromyces, Absidioides and Rhizopoides He used the colour of the colony and specialized organs for classification Zycha (1935) used the presence or absence of thallospores (Kugelgemmen) and has divided *Mucor* into seven sections

a Spores globose — 1. SPHAEROSPORUS
aa Spores not globose
b Turf 0 5–3 mm high, sporangia not over 45 μ in diameter — 2 RAMMANNIANUS
bb Turf more than 3 mm high
c Turf delicate, at first white, later gray or brown, sporangiophores richly branched, sporangial walls fragile or slowly diffluent
d Gemmae in sporangiophores numerous, spore short, oval — 3 RACEMOSUS
4 Gemmae in sporangiophores scarce or lacking, spores more than twice as long as broad — 4. FRAGILIS
3 Turf remaining white, yellow or gray, spore wall diffluent
d Turf usually less than 20 mm high, sporangia less than 100 μ in diameter — 5. HIEMALIS
dd Larger species and primary sporangiophore more or less sympodially branched — 6 FLAVUS
ee Primary sporangiophores not sympodially branched, sporangia large, 100-300 μ no gemmae — 7 MUCEDO

Hesseltine (1954) added two more sections

GENEVENSIS: It includes forms where the sporangiophores are not or at best a few are spherical They are homothallic, due to which zygospores are always present. No member of this section has so far been reported from India

MACROMUCOR: It includes forms with large sporangia (above 500μ in diameter), sporangiophores up to 10 cm in height and 50–100μ in diameter, chlamydospores generally absent or may be present in substrate or in aerial parts of old cultures

KEY TO THE SPECIES

Sec I Sphaerosporus

a Thermophilic species — 1 *M pusillus*
aa Grow well at room temperatures
b. Columellae with pointed extensions, spores brown
c Sporangiophores less than 2 mm high — 2 *M spinescens*

cc Sporangiophores more than 1 cm high . 3. *M plumbeus*
bb Columellae smooth
c Spores larger than 8 μ in diameter . . 4. *M dispersus*
d. Giant cells in the substrate
dd. No giant cells in the substrate
f. Sporangial walls breaking at maturity . . 5 *M petrinsularis*
ff Sporangial walls diffluent at maturity . . 6. *M lamprosporus*
d. Turf and sporangia gray to black 7 *M janssenii*
dd Turf and sporangia brown
e. Sporangia 751–20 μ, sporangioles absent 8 *M. globosus*
ee Sporangia 809–0 μ (100 μ maximum), sporangioles present 9 *M sphaerosporus*

Sec. II. Ramannianus

Single species treated by Gilman (1950) 10 *M. ramannianus*

Sec. III. Racemosus

a Sporangia less than 100 μ in diameter
b. Young turf white to golden brown
c No growth at 37°C or above
d Sporangia very variable, columellae usually globose 11 *M racemosus*
dd Sporangia of uniform size, columellae elongate 12 *M christianiensis*
cc Growth at 37°C
d Growth at 37°C limited . 13. *M praini*
dd Growth at 37°C strong . . 14 *M javanicus*
c Spores 5–7 μ long
cc Spores 4–5 μ long . .. . 15 *M. rouxianus*
bb. Young turf gray to gray brown
c Sporangia brown .. .. 16. *M. circinelloides*
cc Sporangia black .. . 17. *M griseo-cyaneus*
aa Sporagnia more than 100 μ in diameter . 18. *M geophilus*

Sec. IV. Fragilis

a. Turf 1–2 mm high .. 19. *M. ambiguus*
aa Turf 2–20 mm high
b Spores of various sizes 6–12 μ long .. 20 *M lausannensis*
bb Spores smaller, 4–7 μ long 21. *M fragilis*

Sec. V Hiemalis

a. Spores long (1 2–3) narrow
b Spores cylindric with rounded ends . .. . 22. *M. subtilissimus*
bb Spores ellipsoid to spindle form 23 *M. luteus*
aa Spores elongate (1 1.5–2) . . . .
b Spores rounded, cylindric, very uniform up to 4 μ long .. 24 *M. microsporus*
bb. Spores longer than 5 μ
c. Monoecious species . 25 *M. genevensis*
cc. Dioecious species . 26. *M. hiemalis*
ccc Zygotes unknown .. .. 27 *M. adventitius*
aaa. Spores oval (1:1–1.5)
b Gemmae present
c. Giant cells present in substrate . 28 *M silvaticus*
cc. No giant cells present in substrate

d Spores regularly elliptic	29 M griseo lilacinus
dd Spores short oval to globose	30 M abundans
bb No gemmae present	31 M corticolus
aaaa Spores various oval and elongate found in equal numbers	32 M varians

Sec. VI. Flavus

a Spores 5–12 μ long	
2 Spores oval to globose (1 1–1 3)	33 M strictus
bb Spores elliptic (1 1–1 7)	34 M piriformis
bbb. Spores elongate (1 2)	
c Turf becoming yellow, not aromatic	25 M flavus
cc Turf becoming gray, aromatic	36 M attenuatus
aa Spores 12–20 μ long	
b Turf rose, floccose, sporangiophores quickly wilting	37 M rufescens
bb Turf white, spores with granulated contents	38 M oblongisporus

Sec. VII. Mucedo

a Spores 5–15 μ long	
b Spores regularly cylindric to elliptic	
c Sporangia yellow to gray blue, spores 8–12 μ long	39 M mucedo
cc Sporangia gray to black, spores 6–8 μ long	40 M saturninus
bb Spores irregularly oval to globose	41 M albo alter
aa. Sproes 30 μ long	42 M mucilagineus

Mucor plumbeus Bonorden

Abh naturh. Ges Halle 8 1864

Syn *Mucor spinosus* van Tieghem, *Ann Sci nat A* 4 312-398, 1876

Turf close, regular mouse gray, about 1 cm deep. Sporangiophores erect, 1 cm long, branched in groups or in sympodia, rarely simple, tapering at the apex All branches terminated by sporangia Sporangia globose, watery, crystalline, but becoming turbid at later stages, lead-coloured or black, with hairs on the margin, 100–300μ in diameter, sporangial wall smooth, colourless, diffluent, incrusted, leaving a basal collarette Columella free, oval or pear-shaped often crowned with a septate stalk, irregular, often swollen at the tip, 22–85μ long, 8–65μ wide, coloured gray or brown Spores globose, hyaline, ash-coloured to slightly black or gray-blue, wall dotted Zygospores globose, yellowish-brown, exine with irregular warts Chlamydospores on mycelium or sporangiophores Budding cells like yeast

Flood (1931) reported that two asthma patients gave positive results with this organism while Lamson and Rogar (1936) found that 12 per cent patients gave positive results for skin diseases

Lendner (1908) found that it produces 4 62 per cent alcohol by fermenting the grape juice

HABITAT: On soil (Thakur and Norris, 1928)

DISTRIBUTION: India (Madras), Austria, Canal Zone, Costa Rica, Czechoslovakia, Denmark, England, Germany, Yugoslavia, Norway, Panama, Switzerland, U S.S R.

Mucor dispersus Oagem

Ann Mycol. 8 1-152, 1910.

Sporangiophores small, on slightly thickened turf of various heights; the larger 2-3 cm high, widely scattered, very delicate, 4-9μ in diameter, waving here and there and usually soon collapsing, branched in monopodial clusters, with a short bent, circinate (often secondarily branched) branchlets, primary as well as secondary branches terminating in sporangia. Smaller sporangiophores 1-2 mm high, usually circinate with small sporangia. Sporangia on primary sporangiophores small, about 50μ with diffluent wall and smaller ones usually truncate or broadly globose, sometimes oval, 17-19μ high, 18-21μ broad. Columellae, with small collarettes Sporangia on side branches as well as those on secondary sporangiophores of various sizes 15-45μ, with spiny (not diffluent) wall. Spore mass translucent, often very small with few (2-4) spores, or occasionally larger, 30-45μ, with numerous spores. Spore size various, 11-13μ, round or slightly elongate, or even rounded-angular. Zygospores not recorded.

Diamond and Duggar (1941) observed that the monochromatic ultraviolet light had lethal effect on its growth

HABITAT: On soil.

DISTRIBUTION: India (Allahabad), Canada, U.S A., Norway, Germany, France, Czechoslovakia.

Mucor recemosus

Beitrage zur Mykologie, Francfort, 1850-1863.

Turf at first white, turning later to yellowish brown, delicate, height variable, 4-20 mm. Hyphae bearing sporangiophores septate, bifurcating Sporangiophores erect, close, branched irregularly in groups, all branches terminating in sporangia. Sporangia, very unequal in size, small, globose, pale yellow, later wax-yellow or yellowish-brown, 20-70μ in diameter (20-80μ, Rugmini, *loc cit*) erect or occasionally incurved; sporangial wall smooth but fragile, persistent, incrusted, leaving a basal collarette after the spores have been liberated. Columella free, globose to avoid, 17-50 × 7-30μ at the base, increasing up to 42μ in the middle. Spores hyaline (yellow inma ss, Rugmini, *loc cit.*) globose and ovoid 5.8μ × 4.3μ (elliptical, 6-10×3-6μ, Rugmini, *loc. cit*). Gemmae in sporangiophores, cylindrical to barrel-shaped, 8×12.8μ Zygospores (when present) globose, slightly striate, 70-85μ in diameter, brown with conic warts. Suspensor straighter than zygospores, not swollen. Azygospores and chlamydospores numerous The latter formed on mycelium, sporangiophores or even columellae, colourless or yellow, with smooth membrane, shapes various, 20-30μ long, 11-20μ in diameter. Budding cells formed in liquid sugar media Mycelium breaks up into oidia (Fig. 34).

Niethammer and Baessler (1954) reported that *M. racemosus* remained viable for 20 months. Eyre (1932) found that it produced lipase in pure culture. According to Horowitz *et al.* (1935), it can disintegrate fats and oils by oxidation. Knoche

et al (1929) noticed that it could convert wood into fodder It is capable of producing arsenal gas on media containing arsenic (Challenger, 1934) Sutherland and Plunkett (1935) found it on man and oranges, Grimes *et al* (1930) on butter, while Colhoun (1938) isolated it from rots of apples in Ireland

Margolin (1942) reported that *M recemosus* attained best growth on maltose Hagem (1910) found that the fungus could use ammonium and nitrate nitrogen Challenger *et al* (1935) observed that it liberated volatile arsenical products when grown on arsenic-containing wall papers According to Lendner (1908), it produced 4 62 per cent alcohol from grape juice

HABITAT On soil (Thakur and Norris, 1928, Roy, 1948), dung of horse, zebra and elephant (Ajrekar and Rajulu, 1931), rabbit dung (Rugmini, 1956)

DISTRIBUTION: India (Madras, Bombay, Saugar, Chinsura), Austria, Canada, Czechoslovakia, Denmark, England, France, Germany, Greenland, Italy, Japan, Yugoslavia, Norway, Switzerland, U S S R , U S A

Mucor praini Chodate et Nechitch

Inst bot Genéve (Ser 5) 6 · 38, 1904

Sporangiophores sympodially branched, 4 cm long Sporangia globose, smooth, slightly transparent, pale brown or yellow to deep brown, 35μ (sometimes 70–90μ) in diameter. Spores ellipsoid or subspherical, hyaline, 6–8 (up to 10) in larger sporangia 3–4 in smaller ones, columella globose or subelongate, hyaline with a basal collarette, 50–54μ in diameter Chlamydospores hyaline, mostly thick walled, smooth, variable in form, ellipsoid, oval, spherical or irregular, larger ones 24μ in diameter. Zygospores not observed

HABITAT· *On fermenting* rice (Hutchinson and Ram Ayyar, 1915)

DISTRIBUTION Sikkim, Ranchi, Chaibassa, Balasore, Rajmahal, Dunka, Sambalpur, Yugoslavia

Mucor javanicus Wehmer

Zbl Bakt II 6 353-365, 1900

Colonies white to dirty white, later becoming brown, or yellowish brown, 1–2 cm high, respond to phototropism, subaerial mycelium containing yellow globules. Sporangiophores branched, 11 6 μ in diameter Sporangia yellowish brown to black, spherical, many-spored, up to 50 μ or 32 2–59 2 μ in diameter, columella spherical to pyriform with collar up to 32 6 μ in diameter and up to 35 μ in length. Spores variously shaped, globose, oval, from 3 × 3 5 μ to 4–5 × 5–7 μ (sometimes 4.9 × 3 2 μ, Raizada, 1957). Chlamydospores generally in chains, but occasionally single, intercalary, 13 7–17 2 μ in diameter Zygospores 50–60 μ, dark brown but not observed by Raizada

Raizada (*loc cit*) found that it could grow well on potato-dextrose agar and

other media at 37° C. Lendner (1908) reported that the fungus produced 2 8 per cent alcohol from juice of grapes

Mucor rouxianus (Calmette) Wehmer

Zbl. Bakt II 6 : 353-365, 1900.

Syn *M. rouxii* Calmette, *Ann Inst. Pasteur* 6 : 605, 1892.
M. indicus Lendner, *Bull. Soc bot. Genève* 21 255-263, 1930.

Turf low, at most 4 mm high, white, yellow or gray, delicate, loose; large, thick-walled, irregular cells may be formed in submerged mycelium Sporangiophores weakly sympodially branched. Sporangia bright yellow or golden brown, usually 50 μ (20-100 μ) in diameter; columellae up to 40 μ high, globose or flattened, often with coloured membrane. Spores oval 4-5 μ long. Chlamydospores black, numerous, on aerial mycelium, of various sizes, up to 100 μ in diameter, wall 7 μ in diameter Budding yeast-like cells appear on submerged portions. Zygospores absent

Abundant fat globules may develop in the mycelium growing on starchy substrate. The globules appear deep yellow in colour.

M. rouxianus is industrially used for the production of alcohol It secretes both diastase and zymase and can produce alcohol directly without matting process More than 5 per cent alcohol is produced in fermentation.
It is sometimes sold as 'Chinese yeast.'

HABITAT: Soil (Raizada, 1957)
DISTRIBUTION: India (Allahabad), Greenland, Morocco.

This has recently been described by Raizada (1957) from the dung of donkey at Allahabad. It appeared in the month of October.

According to the original description the colony is loose, slightly reddish, sporangiophores minute, 1 mm, 7-14 μ thick, branched, rarely simple, 2-3 sporangia subglobose, 50 μ in diameter, light yellowish; columella globose, 20-23 × 28-32 μ, hyaline; spores oblong, rarely subrounded, heterogeneous; chlamydospores abundant, 12-100 μ in diameter, yellowish or brownish; zygospores not seen. Raizada reported that in his specimen the colonies are white, later becoming brown or brownish yellow, phototropic, up to 1 cm high; sporangiophores branched, 12 2 μ thick, bearing sporangia at tip; sporangia slightly yellow when young and golden-brown when old, spherical to pyriform, many-spored, 25 4 to 34 4 μ in diameter. Columellae spherical, with collars 23.2 μ in diameter, sometimes much bigger. Spores variously shaped, globose, oval, 6 4 × 3 6 μ. Chlamydospores very abundant, intercalary and also in chains. 9.2-14 4 μ in diameter. It grows well at 37°C and sporulates well on all the media used by Raizada.

Raizada's isolate is very similar to *Mucor javanicus*. In a personal communication to him, Hesseltine felt that the two species may be synonymous but Naumov (1939) and Gilman (1945) consider it to be a different species It grows slightly taller than *M. rouxianus* (Calmette) Wehmer described by Naumov (1939).

Due to the differences between Raizada's specimen and the type specimen, Hesseltine has mentioned " It is not typical *M rouxii* because it sporulates well and grows somewhat taller than the typical strains so far described "

Mucor circinelloides van Tieghem

Ann Sci nat A 1 5-175, 1875.
Syn *M echinulatus* Paine, *Mycologia* 19 248, 1927

Sporangiophores erect, forming a very short turf, light gray, shining, brownish or bluish, 0 3–1 cm tall, very much branched sympodially, the branches alternating right and left, non phototropic, short and more or less curved, always terminated by a sporangium, secondary branches very variable in length Sporangia sometimes apparently sessile, globose 70–100 μ or 50–80 μ (Gilman, 1950) in diameter, or 32–70 μ (Chaudhuri and Sachar, 1934), gray-brown when walled, erect or slightly incurved, larger ones with diffluent membrane, wall of smaller sporangia persistent, may be incrusted and then leaving a basal collarette, when not incrusted firm and smooth Columella free, hemispheric, spheric or oval, colourless, smooth, 35 × 45 μ or 6–40 μ in diameter, or 20–40 μ, depending on the size of the sporangium (Chaudhuri and Sachar, *loc cit*) Spores globose or elliptic, 3 μ in diameter, 4–5 μ long or 4 × 5–6 μ (Lendner, 1908), smooth, colourless when single, but pale gray in mass Zygospores globose, exine red-brown, covered with prominent spiny warts, longitudinally striate Chlamydospores smooth, colourless, deep along the length of the filament Gemmae as in yeast and *M racemosus*

Niethammer and Baessler (1954) established that *M circinelloides* could remain viable for 20 months.

HABITAT. On soil Sutherland and Plunkett (1934) observed that it may also occur on oranges as well as man.

DISTRIBUTION India (Punjab), Austria, Czechoslovakia, Denmark, Egypt, England, France, Germany, Greenland, Japan, Yogoslavia, Panama, Switzerland, U S.A.

Mucor fragilis Bainier

Ann. Sci nat. A (Ser 6) 19 : 200-216, 1884

Turf gray to brown, of various heights ranging from 2–15 mm Sporangiophores erect, about 6–15 μ in diameter, usually with marked sympodial branching, helicoid. Sporangia, when moist, yellowish, white to gray, becoming olive-brown at later stage, when dry beige to gray-brown, later oliver-brown; small 35–86 μ, wall more or less slowly fragmenting. Columellae globose to oval, smooth, hyaline, up to 50 μ high with a more or less marked collarette. Spores dark brown in mass, elliptic to cylindrical, twice as long as wide, 2–4 × 4–8 μ Mycelial gemmae detached

Zygospores numerous in winter and spring, black, spherical, 50 μ in diameter. The following variations have been observed by Raizada (1957); colony fast-growing, gray, turning brown at later stage, 1–1.5 cm high. Sporangiophores strongly branched,

sympodial, phototropic, 11 52 μ in diameter, with septum below the sporangium. Sporangia borne singly at the tip of a slightly bent sporangiophore, gray, brownish black when mature, spherical (sometimes the basal portion of the columella also visible), 45 4–62 μ in diameter, wall encrusted Columellae globose, oval, 26 8–30.2 μ in diameter, flattened at the base with sporangial wall attached to it Spores globose, oval, slightly cylindrical, 3.4–6 4 μ in diameter, yellowish green. Zygospores not seen.

HABITAT: On man and oranges (Southerland and Plunkett, 1934); soil (Zycha, 1935); dried and decayed leaves of *Mangifera indica* (Raizada, 1957)
DISTRIBUTION: India (Allahabad), Germany, U.S A

Mucor luteus Gleditsch

Methodus Fungorum Berlin, 1753

Turf 1–5 cm (or only 1–2 cm) high, close, orange-yellow in colour, small side branches in cymes, sporangiophores delicate, 6–14.5 μ (or 6–12 μ) in diameter though usually only 8–10 μ . Mycelium and sporangiophores filled with yellow pigment which lends the characteristic colour to the turf. Sporangia globose, 40–70 μ, usually 50–60 μ (or 35–60) in diameter, at first white, later turning yellow, sporangial wall diffluent, smooth Columellae more or less globose, 16–48 μ (12–30 μ), often somewhat broader than high, colourless or somewhat yellow Collarette as small recurved membrane Spores very variable in size and shape, usually thin cylindrical to ellipsoid or spindle-shaped, 1.5–6 μ broad, 3–16 μ long, (or 4 2 $\times$ 1 2 μ , the larger 7.0 $\times$ 2.1 μ the smaller 2 8–1 24 μ). Chlamydospores not seen. Zygospores not observed in Saugar specimen, but when present globose, 40–80 μ, usually 60 μ in diameter. Exine black, with small warts.

HABITAT: On soil (Saksena, S.B. 1953; Rugmini, 1956)
DISTRIBUTION: Saugar (Saugar specimen, *vide* Saksena, S.B. 1953).

Mucor hiemalis Wehmer

Ann. Mycol 1: 37–41, 1093

Turf 2.10 mm in height, white, close and fine, hyphae with numerous oil drops, 7–14, up to 30 μ in diameter. Sporangiophores unbranched or rarely branched, 900–950 μ long and 6.4–8 μ wide, erect, but later becoming prostrate. Sporangia visible to naked eyes, spherical, gray yellow or dark brown to yellowish brown, 48–60 μ in diameter; wall diffluent, leaving a collarette at the base, columella free, globose, ovoid or hemispherical, 28–48 μ or 22 4 $\times$ 27 μ (Rugmini, 1956). Gemmae present, few, barrel-shaped, 21 $\times$16 μ. Spores numerous 7 $\times$ 3.2 μ, ellipsoid or slightly spherical; or hyaline, unequal, oval to elongate, 3–3 5 $\times$ 4 5 μ (Rugmini, *loc. cit.*); spores wall very thin. Zygospores present (absent according to the original description).

Satina (1931) found that the sex of the strain studied by Ajrekar and Rajulu (1931) was +. Thakur and Norris (1928) reported *M. hiemalis* for the first time from

India Niethammer (1941) studied its morphological characters in detail Niethammer and Baessler (1954) found that it remained viable for 20 months

M hiemalis can be parasitized by *Dissophora nodsonii* (Fillipoff, 1932) and by *Piptocephalis* sp (Dobbs, 1942) Burnet (1953) found evidence for the production of naturally stimulating substances by mycelium of this fungus

HABITAT: On dung of zebra, camel (Ajrekar and Rajulu, 1931), and cow (Rugmini, 1956), soil (Mitra, 1935, Rugmini, *loc cit*, Saha, 1945), gizzard of birds (Porges *et al*, 1935), surface washings of *Zizyphus* (Saha, *loc cit*)

DISTRIBUTION: India (Bombay, Allahabad, Saugar, Chinsurah, Calcutta), U S A

Mocur silvaticus Hagem

Math-naturw 7 . 1-50, 1907

Turf white or gray, formed of thin slightly dense filaments extending over the surface Hyphae bearing sporangia erect or slightly curved, sometimes sympodially branched, branching more near the tip, with one or two lateral branches, 1-1 5 cm in height, 10 μ in width Sporangia small, globose, 45–70μ (average 44 μ) in diameter, wall diffluent, leaving a basal collarette Columella spherical, rarely ovoid, 25–50 μ in diameter, slightly hyaline Spores very variable in size, short and cylindrical, with subrounded apex, oval or subglobose 3 5-5 × 2 5-3 5 μ (maximum 8 × 6 μ) Chlamydospores numerous, specially at the point of contact with the substrate, ovoid, 16–24 μ in diameter. The erect filaments frequently with large swellings, which become isolated and form round cells, 40-60 μ or rarely more in diameter Zygospores black, opaque, with verrucose wall Azygospores numerous, mostly two-fold, rarely solitary.

Niethammer (1941) studied the morphological characters in detail and reported (1942) that it grew superficially on cellulose sulphite

HABITAT: On surface washings of *Nephelium, litchi* and guava (Saha, 1945)

DISTRIBUTION: India (Calcutta,), Canada, China, Czechoslovakia, England, Germany, Greenland, Yugoslavia, Norway, Switzerland

Mucor mucedo (Linne) Brefeld

Bot. Uters Schimmelp, 11 : 1872

Syn. *M griseosporus* Pavah *Bull Torrey bot. Cl* 44 : 241-259, 1997
M. brevipes Riess, *Bot. Zeit* 129-140, 1853 sensu Zycha, 1935)
M proliferous Schostakouritsch, *Ber. dtsch bot. Ges* 14· 260-263, 1896 Zycha, 1935).

Sterile hyphae creeping, branched, septate. Sporangiophores erect, unbranched, forming a raised turf up to 15 cm high, silvery-gray, dirty yellow or slightly dark, smooth, aseptate, 2–15 cm in height, 30–40 μ in diameter; sometimes 1–4 cm high and 5.4–12 μ thick (Mahju, 1933), wall colourless, contents colourless or tardily

yellow. Sporangia large, terminal, globose, 100–200 μ in diameter, at first yellow, then deep gray or brownish-black, echinulate, 5 4 × 12 μ, membrane very diffluent, leaving a collarette incrusted with needle-shaped crystals of calcium oxalate Columella free cylindric, club-shaped, campanulate or spherical, 70–140 μ long, 50–80 μ wide (in Mahju's (*loc cit*) specimen 40–148 × 6–21 5 μ), yellowish or slightly coloured; wall colourless, contents red orange. Spores elliptic, ovoid or subcylindric, twice as long as broad, size variable in the same sporangium, 6–12 μ long, 3 6 μ wide, maximum length up to 17 μ, or 4 5–17 × 2 5–7 μ (Mahju, 1933), spore wall smooth, hyaline, contents tardily yellow or colourless Zygospores with prominent projections, irregular and dark. 90–250 μ in diameter. Exine black, thickly and very strikingly verrucose, hard and fragile, colourless, with less striking warts On germination, zygospores give rise to sporangia on unbranched sporangiophores (Fig 7 A–F) Chlamydospores absent. *M. mucedo* is remarkable on account of its capacity for alcoholic fermentation of sugars. Under submerged conditions the mycelium breaks into spherical oidia which continue to grow by budding like yeast It remains viable for 20 months Porges *et al* (1938) and Schopfer (1935) observed specific effect of vitamin B_1 on its growth. Lopriore (1895) found that the accumulation of CO_2 in the medium inhibited its sporulation. Challenger (1934) noticed that it produced arsenal gas on media containing arsenic. Fillipoff (1932) and Dobbs (1942) established that it could be parasitized by *Dissophora nadsonii* and *Piptocephalis* sp, respectively. Scharff and Catanei (1944) isolated it from humus in Algeria, and Castellani (1935) from sugar-beet roots

HABITAT: On dung of buffalo, horse, *sambhar* (Mahju, 1933), soil (Bhattacharya and Baruah, 1953).

DISTRIBUTION: India (Punjab, Assam), Austria, Czechoslovakia, Egypt, England, France, Germany, Yugoslavia, Norway, U.S A.

Mucor saturninus Hagem

Ann. Mycol. 8:265-286, 1910.

Colonies dark-coloured, usually lead-gray or lead-black, but sometimes even blue-black, sporangiophores of various heights, the lower forms 1–2 mm high, usually richly monopodially or sympodially branched and forming a lead-black or blue-black turf from the large sporangia; the higher forms 2–3 cm high, more or less scattered, 20–25 μ thick, at first erect, later bent, branched monopodially, with long branches and of characteristic bright lead-gray colour Sporangia of shorter branches at first bright waxy-yellow, then blue-gray, almost black at maturity, of very different sizes, usually 45–180 μ in diameter, with a spiny, non-diffluent wall leaving only a collarette Columella oval, seldom cylindrical in the sporangia of higher branches, frequently collapsed on the base, 60–100 μ high, 50–90 μ broad The secondary smaller sporangia 35–70 μ high, 25–50 μ broad Spores regularly broad, ellipsoid, 6–8 × 4–6 μ or even 4–4.5 μ in diameter. Zygospores not observed.

Rugmini's (1956) specimen differs from the type in having sparing branching, absence of dark-coloured turf and the characteristic spiny wall. Her description is reproduced below:

Turf short, 1–7 mm high, at first white, turning grayish with age Substrate mycelium colourless, aerial white, 17 μ wide Sporangiophores unbranched, erect, up to 680 μ high, rarely branched, generally only once near the end, 14–24 μ thick, uniform throughout or slightly increasing towards the tip, but never decreasing Bigger sporangia becoming dark brown with age, spherical to subglobose, 70–150 μ in diameter Smaller sporangia with shorter sporangiophores, 68–78 μ long and 30–40 μ wide Sporangial wall spiny and non-diffluent Spores dark brown, broad ellipsoid, uniform in size, 5 3–5 6 $\times$ 3 2 μ, a few round, 4 2–4 5 μ in diameter, spore wall thick (Fig 36)

HABITAT: Cowdung (Rugmini, 1956)

DISTRIBUTION India (Saugar), Czechoslovakia, Germany, Norway, U S A , New Jersey.

Mucor hygrophilus Oudemans

Arch neerl Sci (Ser 2) 7 1902

Hyphae stalk-like, creeping, branched and continuous Fertile hyphae simple, hyaline, cylindrical, 8 μ thick Sporangia olivaceous, spherical, 36–42 $\times$ 28 μ with hyaline membrane Columella inferior, ovoid 32 $\times$ 24 μ Spores elliptical, ovoid 5–8 $\times$ 3–6 μ numerous, yellowish chlamydospores

Gilman (1950) regards *M hygrophilus* as a species of uncertain position

HABITAT On cotton fibres (Ahmad and Gulati, (1943), soil (Pistor, 1929)

DISTRIBUTION: India (Bombay).

VIII. PILOEOLACEAE

Pilobolaceae Corda, *Icon. fung.* 2:22, 1837.

Sporangiophores simple or branched, phototrophic, often with adhering droplets, with or without a sporangial swelling, black, cutinized, multispored, sometimes forcibly discharged, sporangial wall persistent with lower portion thin and lighter in colour, containing many sporangiospores and a mucilaginous material, the latter swelling and causing the sporangial wall to break at the base; zygospores nearly smooth, spherical or globose, produced between two parallel or tong-like suspensors at the surface of the substrate, coprophilous

This family is based on *Pilobolus* which was first recognized as a distinct genus by Tode Up to the time of Fries (1832) it was considered to be closely related to *Mucor* and, as such, it was either placed along with it or near it Fries first included *Pilobolus* in Gasteromycetes but later (1823) transferred it to his order II Mucorini in the class Hyphomycetes which included such genera as *Mucor*, *Syzygites*, *Phycomyces* and *Ascophora* Corda (1837) introduced the name Pilobolidae and raised it to the rank of a family He first included only two genera *Pilobolus* and *Chrodostylum*; subsequently in 1882, he added the genera *Pycnopodium* and *Caulogaster* also under it

The genus *Pilaira* was established by van Tieghem (1875) and this as well as *Pilobolus* were placed in tribe Pilobolees Schroter (1886) in luded them in Piloboleі which was regarded as a subfamily of as Mucoraci Fischer (1892) followed Schroter and maintained them as members of this subfamily. Zycha (1935) placed both under the family Mucoraceae

Hesseltine (1955), however, felt that *Pilobolus* and *Pilaira* appear to constitute a well-defined family In both, the zygospores originate in a similar manner, are located on the mycelium and have the characteristic smooth wall They are decidedly different from the zygospores of *Mucor*, *Absidia* and *Phy.omyces* of Mucoraceae, where they are usually produced aerially, have verrucose walls and are sometimes adorned with accessory outgrowths from the suspensors.

KEY TO THE GENERA

1 Not discharging the sporangia violently and without subsporangial swelling.. PILAIRA
2 Discharging sporangia violently with a subsporangial swelling.. .. PILOBOLUS

Genus PILOBOLUS Tode

Schrift Naturf Freunde Berlin, 5 · 46, 1784.
Syn *Pycnopodium* Corda, *Icon. fung* 5 : 18, 1842.
Hydrogera Web. et Wigg., *Prim Holstat.* 110, 1780.

Sporangiophore erect, unbranched, apically enlarged to form a prominent, clavate,

subsporangial vesicle, frequently also swollen at its point of origin from the mycelium, usually separated from the mycelium by a septum and anchored to the substratum by rhizoids Sporangium solitary, apical, discoid to lenticular, many-spored, provided with a central columella of much smaller diameter than the subsporangial swelling, the upper half of the membrane thickened and black, the lower half thin and light-coloured, the mature sporangium discharged with force from the end of the sporangiophore, commonly projected for several feet, the columella being carried away with it Zygospore formed at the point of union of the conjugating branches which lie in such a position as to give the appearance of a pair of tongs

Pycnopodium is interesting on account of the phenomenon of sporangial discharge According to Buller (1921), who has described the details of the process, the neck of the sporangial vesicle ruptures just beneath the sporangium, and a sudden contraction of the sporangiophore results in squirting out a jet of cell sap on which the sporangium is carried through the air The vesicle functions as an ocellus (simple eye), and directs the tip of the sporangiophore towards light so that the sporangium may be discharged through the crevices of the substratum into the atmosphere The sporangial vesicle functions as a lens in much the same way as does a flask filled with water If the rays of sun strike on one side of the vesicle they are refracted through it and converge on the opposite side forming a spot of light The protoplasm thus receives a heliotropic stimulus resulting in growth and elongation on that side of the sporangiophore Consequently, the sporangium is turned towards the light until the rays strike it A condition of physiological equilibrium is then reached and the turning movement ends

Naumov (1939) recorded 18 species of *Pilobolus* and suggested the following key for their identification However, Hesseltine (1956) recognizes nine species only. Eight species have been reported from India

KEY TO THE SPECIES (After Naumov, 1939)

1 Spores similar in the same sporangium 2

I Spores in a single sporangium, variable in size and form, elliptic round, 8–20μ long or very rarely about 25μ, yellow or reddish yellow (gold coloured) Sporangiophores 2–3 mm in height with a subsporangial ovoid or elliptical swelling, 0 5–0 6 mm long *P heterosporus*

2 Spores spherical. 3

Spores elongated 9

3 (2) Sporangiophores present in bundles 4

Sporangiophores non-fascicled 7

4 (3) Sporangiophores 1mm high, spores 3 5–4μ in diameter sporangia yellow with apophysis *P nanus*

5 Sporangiophores exceeding 1mm in height 5

5 (4) Sporangiophores 2–5 mm high 6

Sporangiophores 5–6 mm high, sporangia 100–125μ in diameter Spores 12–15μ in diameter *P argentinus*

6 (5) Spores of 7–8μ irregularly spherical, sporangia of 125–145μ diameter *P minutus*

Spores of 16–23μ diameter, bright yellow, sporangia 160–250μ in diameter *P zianus*

7 (3) Spores of 4 5–6μ diameter, golden yellow *P morinii*

Spores very large 8

8 (7) Sporangiophores 1–2 mm high, spores 10–188μ in diameter, double contour present at the

wall, reddish orange *P. oedipus*

Sporangiophores 2–5 mm high Spores 12–20μ in diameter reddish orange, wall thin *P. sphaerosporus*

9 (12) Sporangiophores more than 10 mm high . . . 10

Sporangiophores less than 10 mm high . 12

10 (9) Spores 6–8 × 3–4 μ almost colourless . . . *P. roridus*

Spores very big 11

11 (10) Spores 12–14 × 10–12 μ, gray-black, sporangiophores 2–5 cm high. Sporangia 500 μ in diameter . . *P longipes*

Spores 12–17 × 11–15 μ, yellowish; sporangiophores 2–5 cm high *P. intermedius*

12 (9) Sporangiophores grouped in bundles . . 13

Sporangiophores not grouped in bundles . . . 14

13 (12) Spores 7–8 μ, sporangia 125–145 μ in diameter, sporangiophores 2–5 mm high. *P. minutus*

Spores 12–16 × 7–8μ, sporangia 300–400μ in diameter, sporangiophores 2–4 5 mm high, golden rose *P. roseus*

14 (12) Upper part of the sporangium presents occasionally a reticulate pattern, bright, formed of hexagonal meshes, spores 8–10 × 5–6 μ, pale yellow, sporangiophores 5–10 mm high *P crystallinus*

Never with reticulate pattern . 15

15 (14) Spores 12–20 × 6–10μ, yellowish orange, sporangiophore 2–5 mm high *P. kleinii*

Spores less big 16

16 (15) Spores not more than 9μ long trophocysts 570–720 × 340–400 μ, bright yellow; sporangiophore 1 8 mm high thickness towards apex 140–160 μ, towards the base 120 μ, subsporangial swelling 800–1000 × 640–800μ Columella transparent, not coloured, 250–370 × 180–270 μ, sporangia hemispherical, blue black, warty, 430–510 × 240–400 μ spores elliptic with slender wall 6 5–8.5 × 5.6 μ, yellow . . *P. schmidtii*

Spores more than 10μ long 17

17 (16) Spores 10–12 × 8–9 μ, golden yellow, sporangia 250–300μ in diameter, sporangiophores 1mm high . . *P pullus*

Spores 10–12 × 8–10 μ 'yellowish, basal swelling immersed in the substratum, sporangiophores yellowish . . . *P lentiger*

Pilobolus nanus van Tieghem

Ann. Sci nat A 4:312-398, 1876

Mycelium hyaline and joined, 5–6 fused together, septate or continuous. Sporangiophores short, 1–1 5 mm high, 117 25–134 μ across, base fusoid, 211–276 μ thick; head globose, 50 25–586 35 μ in diameter. Sporangium globose, with yellow cuticle, minute, verrucose, dark gray, 335 μ in diameter. Spores spherical, hyaline, minute, usually 3 5–4 μ or 3 7–5 5 μ (Ginai, 1936) in diameter

HABITAT: On dung of deer and donkey (Ginai, 1936)
DISTRIBUTION: Punjab.

Pilobolus minutus Speg.

Anal Soc cient argent, In 158-192, 1880.

Syn *Pilobolus oedipus* (Montagne) Zycha, *Mem. Soc. Linn. de Lyon*, 1826 Montagne.

Sporangiophores superficial, gregarious (in loose clusters), 2–2.5 mm high; at first filiform, then swollen at the apex and elliptical at the base, hyaline; base bulbous,

tapering downwards, covered with minute drops of water Sporangium lens-shaped, soft, grayish, 125–145 μ (rarely 3 mm Mahju, 1933) in diameter Spores elliptic to spherical, hyaline, angular, 7–8 μ or 8–9 μ (Mahju, *loc cit*)

HABITAT. On dung of horse and buffalo (Mahju, 1933)
DISTRIBUTION. Punjab

Pilobolus morinii Sacc.

Syll. fung 17 1905

Vegetative mycelium inconspicuous, embedded in dung Sporangiophores simple, unbranched, differentiated into trophocyst and sporangiophore proper Trophocyst oval, 56–290 × 600–710 μ, demarcated from the main hyphae by a septum Sporangiophores erect, stiff, bright and filled with oil globules, 4–6 mm high, 160–170 μ wide Sporangium positively phototropic, divided into sporangial vesicle and sporangium proper, vesicle swollen, orange in colour, contents with oil globules, 480–700 × 560–800 μ, sporangium proper discoidal, 400–590 μ in diameter, wall thickly cuticularized, persistent and not rupturing easily Spores discharged violently to a distance of 10–12 cm by breaking loose from the vesicle when mature, brown to yellow, spherical, sometimes a few quadrangular ones also present, 8–9 6 μ in diameter, spore wall smooth and distinctly double-layered

HABITAT: On horse dung (Rugmini, 1956)
DISTRIBUTION: Saugar

Pilobolus roridus Persoon

Synop. fung. 1·1801.
Syn. *Pilobolus microsporus* Klein Pringh Jahrb 8 334, 1872

Vegetative mycelium inconspicuous, sunken in substratum Sporangiophores filamentous, simple and unbranched, differentiated into trophocyst and sporangium proper; trophocyst bulbous 80–150 × 280–480 μ, cut off from the rest of the mycelium by a septum, sporangiophore proper white very thick, stiff and erect, 4–6 mm in length, and 40–80 μ wide Sporangium enlarged into subsporangial vesicle below, 250–390 × 300–500 μ ; sporangium hemispherical, flattened, brown, discoidal with a diameter varying from 300–400 μ, some small, circular, 200 μ, sporangial wall thickly cutinized, black, persistent, not breaking off early, sporangia shot out violently, reaching a distance up to 10–12 cm Spores oval, or elliptical, colourless, light yellow or slightly brownish; spore wall thin and smooth, 6–3 × 3–4 μ in size in the type, or 4–6 × 8–11 μ (Rugmini, 1956)

HABITAT: On horse dung (Rugmini, *loc cit*)
DISTRIBUTION: Saugar.

Pilobolus longipes van Tieghem

Ann. Sci. nat. 4: 312-398,1876.

Mycelium yellow when young. Hyphae bearing the sporangium filamentous. Basal mycelium long, extending, subcylindrical, yellow Sporangiophore erect, elongated, 1.8–2 mm high, apex globose, base bulbous. Sporangium 310–400 μ in diameter; yellow when young, becoming dark later Spores ellipsoid to subspherical, 9–12 $\times$ 8–11 μ, epispore rough, thick, cartilage-like

HABITAT: On dung of buffalo, horse, and deer (Mahju, 1933).

DISTRIBUTION: Punjab.

Pilobolus intermedius (Coem) Karsten

Mycol Fennica 4:73,1878.

Syn. *P kleinii* v. *sphaerospora* Coem., *Bull. Ac. Roy. Bot. Belgique* 15.536, 1863.

Sporangiophores simple and typically unbranched, differentiated into a trophocyst and sporangiophore proper; trophocyst 490–1540 $\times$ 290–390 μ, cut off from the rest of the mycelium by septum; sporangiophore proper yellow, the colour deepening towards tip, 2–5 or 2-4 cm long, 170–240 μ wide Sporangium divisible into the sporangium proper and the subsporangial vesicle, vesicle 460–490 $\times$ 950–770 μ; sporangium hemispherical, black, with a diameter varying from 520–580 μ; sporangial wall thickly cuticularized, black, persistent, not breaking off easily; sporangia shot out violently reaching a distance up to 25 cm. Columella pale blue, cylindrical. Spores spherical or subspherical; oval or ovate with few spherical ones (Rugmini, *loc. cit.*); light yellow, smooth, 12–17 $\times$ 11–15 μ wall thick, double-layered Spherical spores 8–11.2 μ in diameter, oval and ovate ones 9–9 6 $\times$ 9 6–16 μ (Rugmini, *loc. cit.*).

HABITAT: On horse dung (Rugmini, *loc. cit.*).

DISTRIBUTION: Saugar.

Pilobolus crystallinus (Tode) van Tieghem

Ann. Sci nat. A. 1:5-175, 1875

Syn *Hydrogera crystallina* Wigg., *Prim. Fl. Holstat.*, p. 110, 1780.
Mucor obliquus Scopoli, *Fl. Corniolica*, p. 494, 1772.
M. urceolatus Dickson, *Fasc. Pl. Crypt.*, 1:1785.

Hyphae bearing sporangia graceful, clear like dew, yellowish Sporangiophores slender, 5–7 mm or even 4-4.5 mm high, apex swollen, club-shaped. Sporangium hemispherical, 300–310 μ in diameter, black, cuticle verrucose reticulate. Columella cone-shaped, bluish. Spores numerous, of uniform shape, elliptic; epispore thin, 6.2–9 $\times$ 3.7–4.5 μ (7–10 $\times$ 5 6 in type specimen), dilute blue in colour (Fig. 15c) for zygospore.

HABITAT One dung of horse and buffalo (Mahju, *loc cit*)
DISTRIBUTION. Punjab

Pilobolus kleinii van Tieghem

Ann. Sci nat. A. 1:312-398, 1876.

Hyphae bearing sporangia swollen and inflated at apex, graceful, dew-like Sporangiophores 2.4 mm tall; 83 75 117.25 μ across, arising from a triangular base, rhizoidal connections at both the angles Apex inflated 418 75–469 μ thick Sporangium globose, uniformly coloured with verrucose outline, columella conical, when constricted in the middle ending into a cyclindrical form upwards Spores unequal, spherical to ellipsoid, 12 95 $\times$ 5 55–7 μ (12–15 $\times$ 6–9 μ in the type) (Fig 15A, B)

HABITAT· On dung of deer and donkey (Ginali, *loc cit*).
DISTRIBUTION· Punjab

IX. THAMNIDIACEAE

Thamnidiaceae Brefeld, *Bot. Unters. Schimmelpilze*, 4; 161, 1881.

Mycelium *Mucor*-like; sporangiophores dichotomously or irregularly branched or with branches in a whorl-like arrangement hyaline, smooth-walled. Sporangia and sporangiola usually borne on the same sporangiophores, light-coloured, bearing a globose sporangium or a terminal spine (terminal spine and sporangium absent in *Cokeromyces*); branches of the sporangiophore ending in sporangiola or sharp-pointed spines Sporangiola usually with persistent walls, borne on straight or circinate stalks, globose or pyriform, one to few spored, often without a well-developed columella Sporangia multispored, deliquescing, with columellae Zygospores formed between two unappendaged suspensors, not enclosed by a hyphal envelop.

The members of this family are usually saprophytic, generally preferring rather low temperatures. They have been treated differently by various workers Brefeld (1881) followed by Lendner (1908) established two families, Thamnidieen and Chaetocladiaceae, to include the types now included in this family But Schroter (1886), followed by Fischer (1892) recognized only the family Chaetocladiaceae Naumov (1939), on the other hand, reduced both Thamnidiaceae and Chaetocladiaceae to a single tribe Thamnidieae in the family Mucoraceae. Zycha (1935), however, merged both Chaetocladiaceae and Thamnidiaceae into Thamnidiaceae, and within this family he included *Helicostylum, Thamnidium, Chaetostylum, Chaetocladium* and *Dicranophora.*

Hesseltine (1956) felt that the basic characters of the family are represented by *Thamnidium*, which has the sporangium at the tip of the main axis of the sporangiophore, while globose sporangiola are borne at the ends of all the branches, which are repeatedly dichotomously branched. This situation leads to that found in *Chaetostylum* where some branches end in terminal spines, instead of sporangiola. Typical terminal sporangium is, however, found at the end of the sporangiophore *Chaetocladium* represents the end of the development in which the sporangiola have been reduced to one-spored structures and the large *Mucor*-like sporangia are completely lacking A fourth genus, *Helicostylum*, is closely related to *Thamnidium*, but has circinately borne sporangiola which are mostly pyriform in shape. A recently described genus, *Cokeromyces*, possesses only circinately borne sporangiola and has typical *Mucor*-like zygospores, but fails to have any large sporangia or sterile spines This may also be included in this family. It does not appear desirable to retain *Dicranophora* in this family as it rightly belongs to Mucoraceae.

KEY TO THE GENERA

1. Sporangiola never borne circinately
   Sporangiola never pyriform 3
1. Sporangiola borne circinately, typically pyriform or globose 2
2. Terminal sporangia never present, homothallic . . . . . COKEROMYCES

2 Terminal sporangia present, heterothallic	HELICOSTYLUM
3 No spines at the ends of branches	THAMNIDIUM
3 Sterile spines at the ends of branches	4
4 Several sporangiospores to a sporangiolum	CHAETOSTYLUM
4 Single spored sporangiola only	CHAETOCLADIUM

Genus **HELICOSTYLUM** Corda

Icon fung 5· 18, 1842

Syn *Hynaldia* Schulzer V Muggenburg, *Verh zool-bot Ges Wien* 16 37, 1866
Thamnidium (fide *Mycologia* 47 344, 1955).

Lateral branches of the sporangiophore monopodially or cymosely branched, the ultimate branches circinate, in some cases the central axis terminates in a spine

Five to six species are known but only one has been reported from India Fitzpatrick (1930) treats *Helicostylum* as a subgenus of *Thamnidium* under the family Thamnidiaceae.

Helicostylum pyriformi Bainier

These, Paris, p 136, 1882

Turf 4-6 cm in height, white, turning to gray Sporangiophores upright, 1-4 cm long, 19-34 μ wide, terminating at the apex either in a suitable spine like hypha or a columellate sporangium From the main axis of the sporangiophore arise whorls of branches at different nodes, 2-4 circinate branches arise from such whorled branches and end in sporangiola, whorls 2-8, including the one near the apex Terminal sporangium (when formed) globose, many-spored, 168 μ or 80-150 μ in diameter, when absent, a spine-like, 20--60 μ long hypha is produced Sporangiola pyriform, 21 μ or 16-20 μ (Rugmini, 1956) in diameter, columellate, with 8-20 spores. Columella ovoid, broad or hemispherical, up to 13 μ wide, ovoid, smooth-walled. Spores alike both in the terminal sporangium and sporangiola, oval, bluish or greenish, ovoid, smooth-walled, 8 5 $\times$ 4 4 μ or 4-6 $\times$ 3-3 5 μ

HABITAT On dung of camel, elephant (Ajrekar and Rajulu, 1931), horse, goat and lizard (Rugmini, 1956)
DISTRIBUTION: Bombay, Saugar

Genus **THAMNIDIUM** Link ex Wallrath

Fl. Kryptog. Germ 4·324, 1833

Syn *Helicostylum* Corda, *Icon fung* 5·18, 1842, *Bulbothamnidium* Klein, *Verh. Zool.-bot Ges Wien* 20 557, 1870
Chaetostylum van Tieghem et le Monnier, *Ann Sci nat A* 17 328, 1873
Melidium Eschweiler ex Fries, *Syst Mycol* 3· 330, 1832

Sporangiophore erect, consisting of a cylindrical central axis, usually terminated

by a single, large, many-spored sporangium, and lateral branches bearing numerous, small, few-spored sporangiola (Fig. 37) Lateral branches usually several times divided, the ultimate branches straight or circinate, terminating in sporangiola or tapering into sterile spines. Sporangium provided with a prominent columella, sporangiolum lacking a columella, containing 1–20 or more (usually 4) spores Spores in sporangia and sporangiola similar. As far as known, the formation of zygospore is similar to that of *Mucor* and it is produced from approximately equal gametangia

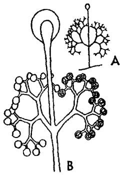
Individual sporangiophores bearing only sporangiola and others bearing only terminal sporangium are occasionally present.

Of the three species known, only one has been reported from India.

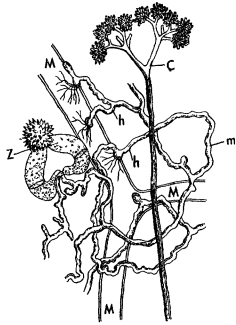
Thamnidium elegans Link

Ges. Natf Fr. Berlin 3:31, 1809

Turf 3 cm high, sporangiophore bearing a terminal sporangium, 100–200 μ in



37



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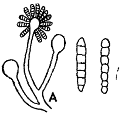

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FIG 37. *Thamnidium.* A, habit; B, sporangiophore (After Fischer).

FIG. 38 *Piptocephalis fresiniana* De Bary. M, mycelium with haustoria, h, which penetrate the hyphae of *Mucor mucedo*, Z, zygospore with two suspensor, C, conidiophore

FIG 39 *Syncephalastrum* A, sporangiophore (After Gilman)

diameter with a columella 50–70 μ wide, 62–90 μ long Sporangiolar branches often arising verticillately from sporangiophores but beyond this branch dichotomously, the length of each branch diminishing in proportion to its forking, first branch from the place of insertion on the principal filament to the first fork 150–200 μ long, the arm of the first order 40–60 μ long and the last one 4 6 μ long and 2 μ in diameter Sporangioles very variable in size, up to 24 μ in diameter, the smaller ones with not more than 4, or even 1 spore Spores of all sporangia similar in size, 6–8 μ × 8–12 μ. Zygospores apear on mycelium round, black, exine verrucose, black, intine yellow (Bainier, 1884)

Rugmini (*loc cit.*) observed the following characteristics in this species

Turf on malt extract white-gray becoming dark-gray to black with age, about 1 5 cm in height Sporangiophores erect bearing *Mucor*-like terminal sporangium, 90–150 μ in diameter Columella subglobose, 48–60 μ in diameter The lateral branches divide in whorls and repeatedly branch dichotomously until the last ones bear sporangia The length of the branch diminished in proportion to its forking The first arm from the place of insertion on the principal sporangiophore to the first fork is 150–180 μ in length, the next one 30–35 μ, while the last branch 8–9 μ in diameter

HABITAT: On soil (Rugmini, 1956)
DISTRIBUTION: India (Saugar), Czechoslovakia, England, U S A

X. PIPTOCEPHALIDACEAE

Piptocephalidaceae Brefeld, *Bot. Unters. Schimmelpilze*, 1 : 1-64, 1872.

Mycelium hyaline, delicate, branched, sporangiophores branched or unbranched, modified sporangia (merosporangia) cylindrical or elongate, relatively few-spored, sporangiophores arranged in a single row, sporangial wall deliquescing; zygospores formed between tong-like suspensors, but said to be *Mucor*-like in one genus, never surrounded by mycelium; mostly obligate parasites on other Mucorales

De Bary (1865) established the genus *Piptocephalis* and later van Tieghem and le Monnier (1873) added *Syncephalis* to Piptocephalidaceae. Subsequently, van Tieghem (1875) described a third genus *Dispira* and included these three within his tribe Syncephalidees Brefeld (1881) created this family, this was accepted by Schroter (1886) who added a fourth genus *Syncephalastrum* to it. Fischer (1892), however, changed the name of the family to Cephalidaceae, and this was followed by Lendner (1908) and Zycha (1935). Besides the four genera mentioned above, Zycha (1935) added *Coemansia, Kickxella* and *Spinalia* to the family. Naumov (1937) divided it into two families with Syncephalastraceae including only *Syncephalastrum*, and Cephalidaceae including *Syncephalis, Piptocephalis* and *Dispira*. Hasseltine (1955), however, included *Syncephalastrum, Syncephalis, Dispira* and *Piptocephalis* in Piptocephalidaceae He suggested the following key for the family.

1 Saprophytic or facultatively parasitic on other Mucorales, sporangiophores not dichotomously branched . . .. . . SYNCEPHALASTRUM
1. Obligate parasites, usually on other Mucorales (*Dispira* is a possible exception)
2. Sporangiophores unbranched or if branched branching dichotomously . .. 2
2. Sporangiophores dichotomously branched, always several times .. 3
2. Sporangiophores unbranched (except in one species *S furcata* once branched) SYNCEPHALIS
3. Some of the branches prolonged into sterile prongs, sporangiferous heads not deciduous . . ..DISPIRA
3. All the branches terminating in sporangiferous heads, the later deciduous ..PIPTOCEPHALIS

Genus SYNCEPHALASTRUM Schroter

Kryptogfl. Schlesien 3:217, 1886

Mycelium wide-spreading, abundantly branched. Sporangiophores erect, lacking basal rhizoids, repeatedly branched, each branch apically dialated to form a globose head, bearing rod-shaped sporangia on the sterigmata, sporangiophores formed simultaneously and assuming the aspect of chains of conidia as in related genera. Zygospores unknown Fitzpatrick (1930) recognized six or seven species under this genus, but Hesseltine (1955) recognized only one to three species. So far, only one species has been reported from India

Syncephalastrum racemosum Cohn

Kryptogfl Schlesien 3 27, 1886

Turf about 6 mm high, mycelium with holdfasts which connect with short rhiziods that soon become over grown, at first white, later becoming silvery gray, 4–5 mm high. Sporangiophores vigorous, at first unbranched, later richly branched in sympodial manner, with strongly curved laterals, without any cross wall at the insertion of lateral branch, 13–16 μ or 6 4–7 6 μ (Rugmini, 1956), fruiting heads globose or oval, 22–70 μ wide, brown or gray with numerous small warts to which the merosporangia are attached Each branch ends in a vesicle 27–42 μ in diameter Merosporangia thin and elongate tubular 20–25 × 3–5 μ with 8–10 spores arranged in a linear fashion Spores 5–10, irregular in size, 3–4 μ in diameter (in the type), or colourless, spherical, 3 5 μ in diameter (Rugmini, 1956), spore wall smooth and double-layered with thick exine and very thin intine

HABITAT On rotting vegetables, surface-washings of litchi, guava, and *Zizyphus* (Saha, 1945); soil (Rugmini, 1956)

DISTRIBUTION. India (Calcutta, Allahabad, Madhya Pradesh), Canada (Bisby *et al*, 1933)

Genus SYNCEPHALIS van Tieghem et le Monnier

Ann. Sci. nat. A. (ser 5) 17. 327, 1873

Mycelium parasitic on other Mucorales, or saprophytic, attached to the host hyphae by suckers and sending in delicate thread-like haustoria as that of *Piptocephalis*; fertile hyphae erect, straight or apically circinate, provided at the base with prominent rhizoids, apically dilated to form a clavate to globose enlargement, which in some species bears rod-like sporangia directly on sterigmata, but in other forms more or less elongate branches which are provided at the tips with sterigmata bearing sporangia Spores in a sporangium more or less definite in a given species, in some only 2–3 at maturity, appearing like a chain of conidia, under moist conditions all the spores on the head held together in a spherical mass in a droplet of water Zygospores formed in the same manner as in *Piptocephalis*, conjugating branches more or less coiled about each other.

About 25 to 30 species are known, but only four of them have been reported from India.

a. Basal cell with a single part sporangium	*S depressa*
aa. Basal cell with 2–5 part sporangia	
b. Sporophores straight	*S sphaerica*
bb Sporophores recurved	
c Sporophores inflated below head, spores 10–12	*S. cornu*
cc. Sporophores not inflated, spores 6–8	*S reflexa*

Syncephalis cornu van Tieghem

Ann. Sci. nat. A 17. 372, 1873

Syn. *S. curvata* Bainier, *Ann Sci nat A* (ser 6) 25 70-204, 1883.

Hyphae bearing sporangia 170-200 μ long, rhizoids small, 11 μ broad at the base,

26 μ at the apex, sometimes constricted near the apex then 9 μ broad At length vesicle rounded, 30–33 μ in diameter Sporangia smaller, bladder-like. Spores elliptical $10–12 \times 4–5$ μ, yellow and somewhat broad Zygospores globose, 24–28 μ in diameter

HABITAT: Parasitic on *Cunninghamella echinulata*, on soil (Ramakrishnan, 1953; 1955)

DISTRIBUTION: Madras.

Syncephalis reflexa van Tieghem

Ann. Sci. nat. A 1:5-175, 1875

Hyphae for the most part 100–120 μ high, 9–12 μ broad, vesicle inflated, globose warted, 40–45 μ long Sporangia simple, cylindrical, 35 μ long Spores ellipto-cylindrical, 7–8 $\mu \times$ 3-4 μ.

HABITAT. Parasitic on *Cunninghamella bertholletiae*; on soil (Ramakrishnan, 1953, 1955)

DISTRIBUTION : India (Madras)

Syncephalis sphaerica van Tieghem

Ann. Sci. nat. A. 1: 5-175, 1875.

Growth sparse or sub-gregarious, sporangiferous hyphae erect, white, about 420–720 μ long (1,000–1,5000 μ in Ginai's specimen), base broader, flattened about 67–70 μ across, gradually attenuated upwards to a thickness of 25 12 μ, head sphaeroid about 100 μ in diameter, crowded with spores; spores cylindrical, uniform, smooth, hyaline, 3–4 $\times$ 8–10 5 μ or 4.17–5 01 $\times$ 6.8–0 35 (Ginai, 1936)

HABITAT: On donkey dung (Ginai, 1936)

DISTRIBUTION: India (Punjab)

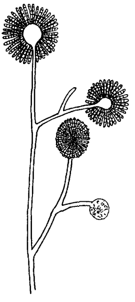
Syncephalis nodosa van Tieghem

Ann. Sci Nat. A. 1:5-175, 1875.

Sporophores separate, erect, unbranched and stout, with rhizoids at the base which very often fuse with each other forming knotty extensions (Fig 44 A–C), walls smooth (Fig. 44 D), at maturity developing 2–4 knot-like swellings (Fig 44 F), 100–160 μ high, 5 μ wide, except at swollen areas where 8 μ wide, at tip the sporophore enlarges into a vesicle, about 20 μ wide Basal cells deltoid to somewhat rectangular, 3–5 with as many spore chains, generally with two spores in each chain Spores barrel-shaped proportionately very large, 8–10 $\mu \times 6$ μ, slightly verrucose to warty (Fig. 44 G, H). Zygospores not seen

HABITAT· Parasitic on *Mucor* sp growing on dung of wild rat (Mehrotra, 1959)

DISTRIBUTION: Allahabad.



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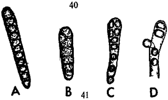

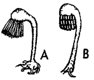

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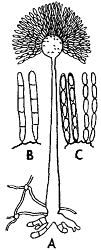

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Fig 40 *Syncephalastrum racemosum* Cohn General habit (After Naumov)

Fig. 41. *Syncephalastrum racemosum* Cohn A, normal sporangium containing single row of mature spores, B, sporangium containing one lateral spore, C, spores escaping through the base of a mature sporangium, D, crushed sporangium (After Thaxter, 1897)

Fig 42 *Syncephalis reflexa* van Tiegh A–B, sporangia before and after spore formation (After Thaxter)

Fig 43 *Syncephalis sphaerica* van Tiegh Sporangiophores and sporangia with spores (After Naumov)

Genus PIPTOCEPHALIS de Bary

Abh. senckenb. naturf Ges. 5:356, 1865.

Vegetative hyphae slender, becoming septate, highly branched, running over the host hyphae and forming small appressoria which penetrate the host wall and give rise to restricted, delicate, branched haustoria Sporangiophores erect, ascending, or recumbent, septate, smooth or appearing longitudinally striate, giving rise to two or more

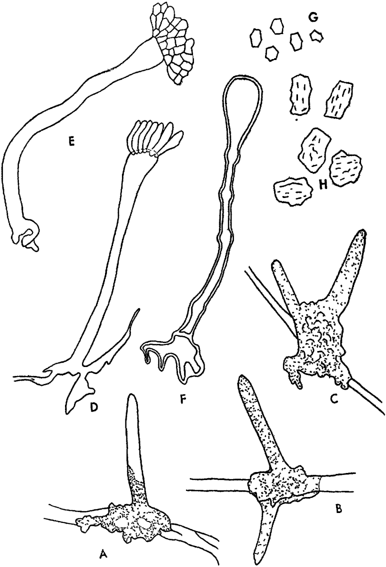


FIG 44 *Syncephalis nodosa* A–C, developing sporophores on a hypha of *Mucor*, D, young sporophore with no differentiation of spores, E, a fully developed sporophore, F, a sporophore on maturity; G, spores, H, spores

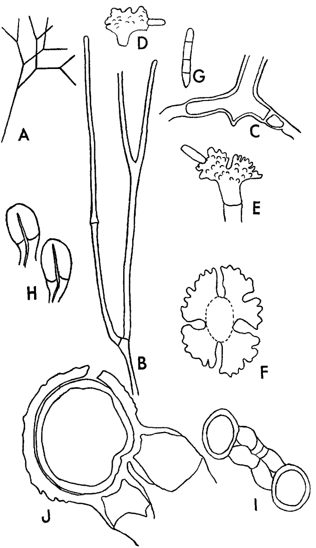


FIG 45. *Piptocephalis de-baryana* sp. nov A, top portion of the sporophore showing the branching pattern, B, part of sporophore, C, base of sporophore, D, head cell with a single spore, E, magnified side of head cell, F, magnified top view of head cell,; G, merosporangium; H–I, a stage in zygospore formation, J, mature zygospore

repeatedly dichotomous branch systems, the ultimate branches producing relatively small enlargements bearing few to many merosporangia containing two or more uniseriate, globose, ellipsoid, cylindrical, or fusiform sporangiospores, terminal enlargements usually deciduous at maturity; merosporangial wall delicate, evanescent; spore heads remaining dry or forming viscous drops. Zygospores globose, usually light-coloured, rough, forming bud-like enlargements and above the joint of fusion of slightly unequal, gametangia, delimited apically by apposed progametangia.

Piptocephalis de-baryana Mehrotra

Proc. nat. Acad. Sci. (India) 30: 370-372, 1960.

Mycelium running over the host hyphae, attached to them at intervals by swollen suckers. Sporophores in mass, tan-coloured against the background of the host, erect or ascending, 5–15 mm in length, upright, the upper 1/5 with 5–8 branches at the tip, lower portions of the sporophore approximately 4.5 μ in diameter, higher up 2.5 μ, still higher up in the ultimate branches 1.5 μ but at the tips enlarging to 2.8–3 μ. Sporophore mostly non-septate, except at the bifurcations, later becoming longitudinally striate; the fertile branch system variously branched with branches differing or equal in length. The ultimate (head-cell) branches 33–84 μ, rarely up to 200 μ in length, not tapering, but slightly swollen at apex. Head-cells deciduous, mostly 10–10.5 μ wide, obconic with bases broad and plane, broader at the apex, highly dichotomized with the margins slightly crenate at the insertion places of the merosporangia, the latter numerous borne on each head-cell, 12–13μ long with generally 4 cylindrical spores. Sporangiospores 2.8–5.6 $\times$ 1.4–1.6 μ (average 4 $\times$ 1.4 μ), smooth and colourless. Zygospores golden-yellow or yellow-brown subspherical to slightly oval, 18–34 μ (mostly between 27–30 μ) in diameter, formed as bud-like enlargements from the fused apices of slightly unequal gametangia borne terminally on apposed progametangia, suspensors smooth, attenuated at the point of attachment with the zygospore, exospore wall with scattered fine tubercles or echinulations, endospore wall smooth, about 24 μ thick. Azygospores also frequently seen (Fig. 45 J).

HABITAT. Parasitic on *Mucor hiemalis* growing on the dung of wild rat (Mehrotra, 1960).

DISTRIBUTION. India (Allahabad).

XI KICKXELLACEAE

Kickxellaceae Linder, *Farlowia* 1·56, 1943

Mycelium hyaline or light-coloured, sporangia absent, conidiophores simple or branched, always with sporocladia, sporocladia somewhat inflated, septate or non-septate, frequently tapering to 1–3 terminal cells and bearing phialides upon its upper or lower surface, phialides simple, hyaline ovoid to elongate, ellipsoid, conidia borne singly at the ends of the phialides, one-celled, sometimes pseudoseptate, hyaline to yellow, elongate, ellipsoid to needle-shaped, sometimes with a capsule at one end, zygospores as those in Piptocephalidaceae

Coemans (1962) described the genus *Kickxella* as a fungus which had sporocladia arranged in a whorl at the end of a single conidiophore, and also bore sporangia and cleistothecia The resulting confusion is described by Linder (1943) in detail Coemans described a second genus *Martensella* with conidia on upper side of sporocladia which were borne singly along the conidiophore, van Tieghem and le Monnier (1873) added a third genus *Coemansia* with the conidia on the lower side It is doubted if these genera are actually distinct Recently, a fourth genus *Linderina* has been described in which the sporangia are neither septate nor clearly pedicellate, the sporocladia are ovoid or dome-shaped and not boat-shaped as those in other genera

Coemans considered *Martensella* to be a Hyphomycetes, but van Tieghem and le Monnier (1873) regarded it to be a member of Mucorales

Zycha (*loc cit*) recognized *Coemansia* and *Kickxella* as members of Phitocephalidaceae, but Naumov (*loc cit*) mentioned them only in the appendix to his Mucorales. Hesseltine (1955), however, recognized Kickxellaceae as a separate family on account of the absence of sporangia and production of sporocladia which bear conidia According to him, the family includes four genera *Kickxella, Linderina, Coemansia* and *Martensella* Of these only *Coemansia* has been recorded from India so far

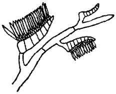
KEY TO THE GENERA

1	Sporocladia in a whorl at the apex of the conidiophore, conidia pseudoseptate	KICKXELLA
1	Sporocladia not in whorl, borne pleuracrogenous on conidiophores, conidia not pseudoseptate	2
2	Sporocladia non-septate, ovoid or dome-shaped but never elongated	LINDERINA
2	Sporocladia always elongate and septate	3
3	Sporocladia always bearing conidia on the lower surface	COEMANSIA
3	Sporocladia bearing conidia on the upper surface	MARTENSELLA

Genus **COEMANSIA** van Tieghem et le Monnier

Ann. Sci. nat A (ser. 5) 17 : 392, 1873

Turf yellow, up to 6 mm high, mycelium creeping, branched and septate Conidiophores unbranched or forked with many septa, merosporangia alternating, boat-shaped, quite broad, many-celled and carrying on their inner surface a number of small basal cells, which bear the spindle-shaped conidia (Fig 46)



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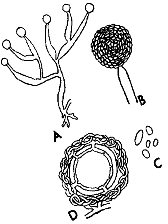

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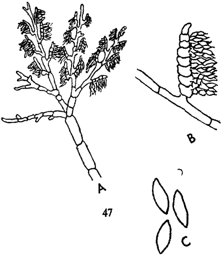

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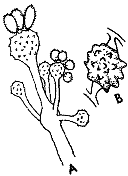

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FIG 46 *Coemansia* A sporangiophore (After Zycha).
FIG 47. *Coemansia erecta* van Tiegh and le Monn A, habit, B, sporangiophore with sporangia; C, spore (After Rugmini, 1955)
FIG 48 *Mortierella* A, habit, B, sporangium, C, sporangiophores, D, zygospore (After Zycha).
FIG 49 *Cunninghamella* A, sporangiophore, B, zygospore (After Lendner)

Coemansia erecta Bainier

Bull Soc mycol Fr 22 392, 1906

Plant body is finger-like, 3–8 cm in height, massive with pseudo-parenchymatous tissue formed of a large number of hyphae interwoven together, forming a central sterile tissue, all round which are produced the conidiophores, at first white and later turning to pinkish or slightly yellowish Mycelium septate Conidiophores erect, septate, branched and rebranched, bearing sporocladia on alternate side Sporocladia boat-shaped, quite broad, transversely divided into 4–8 chambers, 27–30 μ long, each producing conidia only on the lower surface Conidia numerous on each receptacle, yellow or hyaline, one-celled, ovoid to spindle-shaped (Fig 47) 1–2 5 × 6–7 5 μ

HABITAT On faeces of rat (Rugmini, 1956)
DISTRIBUTION India (Saugar), England (from soil)

XII. MORTIERELLACEAE

Mortierellaceae Fischer *Pilze Deut. Oest. Schweiz.* (in Rabenhorst's *Kryptogfl*) 1 : 268, 1892.

Mycelium coenocytic, later septate, branched; sporangiophores simple or branched, hyaline, forming terminal one- to many-spored, globose sporangia, columella absent; zygospores enclosed in a more or less compact covering of mycelium (except in *Haplosporangium*, *Dissophora*, and a few species of *Mortierella*)

Coemans (1863) described *Mortierella* as the first-known member of this family; van Tieghem (1875) placed this under tribe Mortierllees of Mucoraceae. Berlese and de Toni (1888) considered *Mortierella* and *Herpocladium* to be members of subfamily Mortierelleae, while Fischer (1892) elevated it to the rank of a family; his suggestion has been accepted by Schröter (1886) and others Thaxter (11914) added two genera, *Haplosporangium* and *Dissophora*, to this family

Recently, Novotelnova (1950) described a fourth genus *Naumoviella*; but Hesseltine (1955) considers it as a species of *Mortierella* He also does not recognize *Gongronella* of Ribaldi (1952) The type of Ribaldi's genus may be *Absidia butleri*, which has the same habitat and many of the characters of *Gongronella*

Hesseltine recognized only three genera and suggested the following key for their separation.

KEY TO THE GENERA

1	Sporangia with one or two sporangiophores .	HAPLOSPORANGIUM
1	Sporangia with several sporangiophores	2
2	Sporangiophores arising from ordinary vegetative mycelium .	. MORTIERELLA
2	Sporangiophores arising in progression on special fertile hypha:	DISSOPHORA

So far, only *Mortierella* has been reported from India.

Genus MORTIERELLA Coemans

Bull Acad R. Bot Belg (ser 2) 15 : 536, 1892.

Syn *Naumoviella* Novotelnova, *Notul syst. crypt. bot. Acad. Sci. U.R.S.S.* 6 : 155, 1950.

Carnoya Dewevre, *Grevillea* 22 : 1893.

Mycelium very thin and delicate; nutritive mycelium creeping, many times anastomosing. Sporangiophores erect, at first short, at maturity rapidly becoming filiform, with limited growth, simple or branched, very broad below, diminishing to the tip Sporangia terminal, spherical, without columellae, membrane thin, diffluent. Spores spherical or ellipsoid. Zygospores spherical, covered by a thick case. Conidia formed on short side branches on the aerial mycelium, spherical, one-celled (Fig. 48)

Recently, Subramanian (1952) reported *Mortierella ramanniana* var. *angulispora*

(Naumov) Einnemann from soils in Madras, but it is a synonym of *Mucor angulisporus*

Turf gray, about 0 05 cm high Sporangiophore sympodially branched, 3 7–4 μ in diameter Sporangia spherical, 14–16 μ in diameter Columellae globose, 8-11 μ in diameter Spores globose, angular, 2 11 μ in diameter

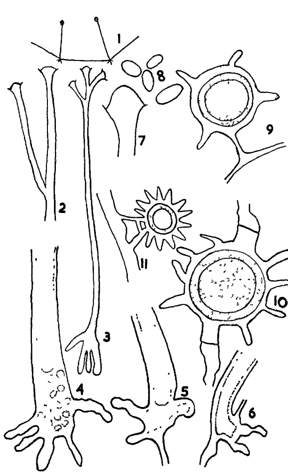


FIG 50 *Mortierella indica* 1, relative position of the sporangiophore and mycelium; 2, top portion of a sporangiophore with two branches, 3, a complete sporangiophore with three branches, 4–6, bases of three sporangiophores showing rhizoids, 7, apex of a sporangiophore showing bulged septum, 8, few sporangiospores, 9, a terminal stylospore, 10, an intercalary stylospore, 11, a stylospore on a double stalk.

Mortierella indica Mehrotra

Indian Phytopath. 1 : 68-71, 1960.

Sporangiophores 100–385 μ, attached at the base by slightly brown to colourless rhizoids; swollen right at the base (not narrow at first), gradually tapering from 8–13 μ at the base to 2.8–3.2 μ at the apex with a bulged transverse septum at the tip, 3–3.5 μ in height; often branched, ramification cymose, branches 42–65 μ long, 2.8 μ at the base to 1.4 μ at the apex. Sporangium 14–22 μ in diameter, colourless, leaving a collar on the sporangiophore on dehiscing, about 50 or slightly more sporangiospores in each sporangium. Sporangiospores elliptical to oval, very rarely globose smooth, 4–11 $\times$ 3–4 μ (average 6×3 μ) in size.

Stylospores intercallary and terminal, 20–30 μ in diameter, borne on a single or double stalk, echinulate to spiny (Fig. 50), spines long, 3–6 μ (generally 5 μ). Zygospores not seen.

XIII. CUNNINGHAMELLACEAE

Cunninghamellaceae Naumov, *Clés des Mucorinees* p 20, 1939

Mycelium coenocytic, later septate, conidiophores branched or unbranched, bearing conidia only on terminal swellings, conidia borne singly, never catenulate, upon variously shaped swollen vesicles, hyaline, one-celled, never appearing as one-celled sporangiola, zygospores, where known, verrucose, borne in ladder-like fashion, and resemble those of *Mucor*, differing from those of Choanephoraceae where they are produced between tong-like suspensors, surface almost smooth

Naumov (1939) proposed this family to include those genera of Choanephoraceae which developed conidia only, these are *Cunninghamella*, *Sigmoideomyces* and *Thamnocephalis* Hesseltine (1955) felt that *Mycotypha* also probably belongs to this family Even though zygospores are not yet known, Fenner (1932) as well as Hesseltine believe *Mycotypha* to be a member of Zygomycetes Hesseltine felt that *Sigmoideomyces* of Naumov was a doubtful genus of this family He, therefore, included only *Mycotypha* *Cunninghamella* and *Thamnocephalis* in this family

KEY TO THE GENERA

(After Hesseltine, 1955)

1 Vesicles upon which the conidia are borne cat tail like, hence extremely elongate and slender — MYCOTYPHA

1 Vesicle globose or short, ovoid — 2

2 Conidiophores mostly ramose, with a vesicular swelling at the apex of each branch, conidiophore rarely simple and terminated by a capitate enlargement — CUNNINGHAMELLA

2 Conidiophores having both sterile branches and branches ending in swollen fertile vesicles, vesicles spherical, borne on oppositely formed branches — THAMNOCEPHALIS

Only *Cunninghamella* has been reported from India

Genus CUNNINGHAMELLA Matruchot

Ann Mycol. 1 43, 1903

Syn *Actinocephalum* Saito, *Bot Mag Tokyo* 19 36, 1905.
Saitomyces Ricker, *J Mycol* 12-61, 1906
Muratella Bainier et Saratory, *Bull Soc mycol Fr* 29 129, 1913

Sporangia never observed in the genus, though occasionally developed under special environmental conditions (Thaxter, 1914) As far as known, asexual reproduction exclusively by means of conidia (Fig 49), conidiophores arising from vegetative hyphae erect more or less branched, sometimes septate, each branch terminated by a capitate vesicle covered with sterigmata bearing small, spiny, unicellular, globose to oval or pyriform, deciduous conidia, the type of branching differing in various species Spores globose, intercalary in the mycelium, heterothallic. Gametangia approximately equal Zygospores rough but not appendaged

Matruchot (1903) considered that *Cunninghamella* belonged to the Mucorales, near *Choanephora*; particularly due to its heterothallic habit. Lendner (1908), however, placed it in Chaetocladiaceae, but Zycha (1935) as well as Fitzpatrick (1930) placed it in Choanephoraceae along with *Choanephora* and *Blakeslea*.

Six species have been described, but only four of them have been reported from India.

KEY TO THE INDIAN SPECIES
(After Gilman, 1950. p. 65)

a. Terminal vesicles more than 50 μ in diameter.

b. Sporangiophores dichotomously branched, lateral branches more than 30 μ long . *C. elegans*

bb Sporangiophores not dichotomously branched; lateral branches less than 30 μ long .. .. *C. verticillata*

aa. Terminal vesicles less than 50 μ in diameter

b Lateral sporangia smaller than terminal . .. . *C. bertholletiae*

bb Lateral sporangia of same size as the terminal sporangia *C. echinulata*

Cunninghamella elegans Lendner

Bull. Herb. Boissier (Ser. 2) 5:250, 1907.

Turf white to silver, spreading, filaments firm and interwoven, 7–13μ wide with abundant oil, circinate portions typical Conidiophores erect with many branches, terminal vesicle 27–35μ in diameter, spherical, smooth; lateral branches lacking, or up to three-whorled, place of attachment to conidiophores swollen, subterminal whorl 38μ long, vesicles spherical, 16–28μ in diameter, smooth, intermediate whorl 24μ long, its vesicle spherical, 14–16μ in diameter, smooth; basal whorl of pyriform branches, 14μ wide, 26μ long, smooth, super branches of varying lengths arising from terminal head. Vesicles spherical. Conidia ellipsoid, 16×12-14μ and 22× 12μ with finely echinulate membrane; smaller conidia 10μ long, 6μ wide

Raizada (1957) reported that sugar alcohols were toxic for this fungus. He also found that 35° C was the optimum temperature for its growth.

HABITAT: On soil (Shaw, 1916)

DISTRIBUTION: India (Pusa), Austria, Canada, Czechoslovakia, France, Germany, Yugoslavia, U.S.A.

Cunninghamella verticillata Stadel

Mycologia 19:248-266, 1927.

Turf silvery white, loose, looking granular on fruiting, 2–4 cm in height. Conidiophores erect, long, 2 cm or more, non-septate, verticillately branched. Terminal vesicle globose to oval, about 50μ (Saugar specimen 35–50μ) in diameter, lateral branches numerous, short, 25–35μ long, subterminal, whorled conidiophores swollen at the point of attachment of the lateral branches. Lateral vesicle pyriform to oval, or oval to roundish (Saugar specimen), about 15μ in diameter. Terminal conidia ellipsoid pointed at the attached end, generally 10 × 13μ, rarely 14–18× 10–12μ (Saugar specimen), very finelly echinulate. Lateral conidia round to slightly oval, bluntly

pointed at the attached end, 8–12 or 7–11µ (Saugar specimen) in diameter, very finely echinulate

It has also been reported from soil in China as well as from alkaline soil in Iowa

HABITAT On soil (Chaudhuri and Sachar, 1934, Roy, 1948, Saksena, S B. 1955)

DISTRIBUTION India (Punjab, Chinsura, Saugar), China, U S A

Cunninghamella bertholletiae Paine

Diss Kiel, p. 35, 1911

Turf grayish white, floccose, filaments closely interwoven, rhizoids tenous Conidiophores erect, irregularly cymosely branched, non-septate Terminal vesicles ovate, **about 33µ long and 25µ** wide or 40 × 25µ (Saugar specimen) Lateral branches variaable, usually arranged in groups at the nodes, numerous, 22–55µ long Lateral vesicles round, about 23µ in diameter Terminal conidia ovate to roundish, 5 × 9µ smooth, or very finely echinulate (Saugar specimen), lateral conidia similar to terminal ones but slightly smaller

Alcorn and Yeager (1938) described it from soils in Idaho

HABITAT On soil (Prakash and Saksena, 1952, Saksena, S B 1955)

DISTRIBUTION: India (Allahabad, Saugar), U S A

Cunninghamella echinulata Thaxter

Rhodora 5·97-102, 1903

Syn. *C verticillata* Paine, *Mycologia* 19 248-266, 1927

C. africana Ma'ruchot, *Ann. Mycol* 1 45-60, 1903

Colonies white, changing to dull white and later becoming lightly brownish white, **very fast-growing, dense, height several cm, conidiophores branched, lateral branches common, main conidiophore very long (several mm) and 9 4µ in diameter, branches up to 22 0µ in length** Main conidiophores bearing terminal vesicles variable in size, **ovate, nearly spherical to ovoid (Fig 8), average size 28 × 35µ, maximum 45 × 56µ or 37.3–43.4µ in diameter (Raizada, 1957), inflated head about 100µ in diameter Conidia globose or ellipsoid, average 10 × 12µ, maximum 18 × 25µ (Type specimen), oval and spherical, 10 4 × 13 6µ and 9 8–11 2µ (Raizada *loc cit*), born on sterigmata up to 3 6µ long, echinulations up to 5µ in length** Zygospores and chlamydospores not seen

It could grow very well at temperatures ranging from 25°–37° C and produced **conidia on a number of media used by Raizada (*loc cit*) He found that sugar alcohols were unsuitable** sources for this organism

HABITAT: On soil (Roy, 1948, Prakash and Saksena, 1952, Raizada, 1957)

DISTRIBUTION: India (Pusa, Chinsura, Allahabad), Egypt, Czechoslovakia, U S A

Matruchot (1903) considered that *Cunninghamella* belonged to the Mucorales, near *Choanephora*; particularly due to its heterothallic habit Lendner (1908), however, placed it in Chaetocladiaceae, but Zycha (1935) as well as Fitzpatrick (1930) placed it in Choanephoraceae along with *Choanephora* and *Blakeslea*

Six species have been described, but only four of them have been reported from India.

KEY TO THE INDIAN SPECIES
(After Gilman, 1950. p. 65)

a. Terminal vesicles more than 50 μ in diameter.
 b. Sporangiophores dichotomously branched, lateral branches more than 30 μ long . . . *C elegans*
 bb Sporangiophores not dichotomously branched; lateral branches less than 30 μ long . . . . *C. verticillata*
aa. Terminal vesicles less than 50 μ in diameter
 b Lateral sporangia smaller than terminal . . . . *C berthollettiae*
 bb. Lateral sporangia of same size as the terminal sporangia *C. echinulata*

Cunninghamella elegans Lendner

Bull. Herb. Boissier (Ser. 2) 5:250, 1907.

Turf white to silver, spreading, filaments firm and interwoven, 7–13μ wide with abundant oil, circinate portions typical. Conidiophores erect with many branches, terminal vesicle 27–35μ in diameter, spherical, smooth; lateral branches lacking, or up to three-whorled, place of attachment to conidiophores swollen, subterminal whorl 38μ long, vesicles spherical, 16–28μ in diameter, smooth, intermediate whorl 24μ long, its vesicle spherical, 14–16μ in diameter, smooth, basal whorl of pyriform branches, 14μ wide, 26μ long, smooth, super branches of varying lengths arising from terminal head. Vesicles spherical. Conidia ellipsoid, 16×12-14μ and $22 \times 12\mu$ with finely echinulate membrane; smaller conidia 10μ long, 6μ wide

Raizada (1957) reported that sugar alcohols were toxic for this fungus. He also found that 35° C was the optimum temperature for its growth

HABITAT: On soil (Shaw, 1916)

DISTRIBUTION: India (Pusa), Austria, Canada, Czechoslovakia, France, Germany, Yugoslavia, U.S.A.

Cunninghamella verticillata Stadel

Mycologia 19:248-266, 1927.

Turf silvery white, loose, looking granular on fruiting, 2–4 cm in height. Conidiophores erect, long, 2 cm or more, non-septate, verticillately branched. Terminal vesicle globose to oval, about 50μ (Saugar specimen 35–50μ) in diameter, lateral branches numerous, short, 25–35μ long, subterminal, whorled conidiophores swollen at the point of attachment of the lateral branches Lateral vesicle pyriform to oval, or oval to roundish (Saugar specimen), about 15μ in diameter. Terminal conidia ellipsoid pointed at the attached end, generally $10 \times 13\mu$, rarely 14–18×10–12μ (Saugar specimen), very finelly echinulate. Lateral conidia round to slightly oval, bluntly

pointed at the attached end, 8–12 or 7–11μ (Saugar specimen) in diameter, very finely echinulate

It has also been reported from soil in China as well as from alkaline soil in Iowa

HABITAT On soil (Chaudhuri and Sachar, 1934, Roy, 1948, Saksena, S B 1955)

DISTRIBUTION India (Punjab, Chinsura, Saugar), China, U S A

Cunninghamella bertholletiae Paine

Diss Kiel, p. 35, 1911

Turf grayish white, floccose, filaments closely interwoven, rhizoids tenous Conidiophores erect, irregularly cymosely branched, non-septate Terminal vesicles ovate, about 33μ long and 25μ wide or 40 × 25μ (Saugar specimen) Lateral branches variable, usually arranged in groups at the nodes, numerous, 22–55μ long Lateral vesicles round, about 23μ in diameter Terminal conidia ovate to roundish, 5 × 9μ smooth, or very finely echinulate (Saugar specimen), lateral conidia similar to terminal ones but slightly smaller

Alcorn and Yeager (1938) described it from soils in Idaho

HABITAT: On soil (Prakash and Saksena, 1952, Saksena, S B 1955)

DISTRIBUTION: India (Allahabad, Saugar), U S A

Cunninghamella echinulata Thaxter

Rhodora 5 97-102, 1903

Syn *C. verticillata* Paine, *Mycologia* 19 248-266, 1927

C. africana Ma'ruchot, *Ann. Mycol.* 1.45-60, 1903

Colonies white, changing to dull white and later becoming lightly brownish white, very fast-growing, dense, height several cm, conidiophores branched, lateral branches common, main conidiophore very long (several mm) and 9 4μ in diameter, branches up to 22.0μ in length Main conidiophores bearing terminal vesicles variable in size, ovate, nearly spherical to ovoid (Fig 8), average size 28 × 35μ, maximum 45 × 56μ or 37 3–43.4μ in diameter (Raizada, 1957), inflated head about 100μ in diameter. Conidia globose or ellipsoid, average 10 × 12μ, maximum 18 × 25μ (Type specimen), oval and spherical, 10 4 × 13 6μ and 9 8–11 2μ (Raizada *loc cit*), born on sterigmata up to 3.6μ long, echinulations up to 5μ in length Zygospores and chlamydospores not seen.

It could grow very well at temperatures ranging from 25°–37° C and produced conidia on a number of media used by Raizada (*loc cit*) He found that sugar alcohols were unsuitable sources for this organism

HABITAT: On soil (Roy, 1948, Prakash and Saksena, 1952, Raizada, 1957)

DISTRIBUTION: India (Pusa, Chinsura, Allahabad), Egypt, Czechoslovakia, U S A

XIV. CHOANEPHORACEAE

Choanephoraceae Fitzpatrick emend. Naumov.
Lower Fungi p. 258, 1930, *Clés des Mucorinees*, p. 97, 1939.

Mycelium hyaline, much-branched, rapidly growing; sporangiola, conidia and sporangia always upon separate stalks, sporangiophores bearing many-spored sporangia or few-spored sporangiola, both with persistent walls, conidiophores divided, bearing dark-coloured, striated conidia; sporangia with columella, often borne circinately, sporangiophores usually with bristle-like structures at each end, browr-coloured, often striate, zygospores smooth or nearly so, borne between two closely appressed suspensors, typically growing on higher plants

Blakeslea and *Choanephora*, which constitute this family, have been known for a long time. The former was described by Thaxter in 1914 and the latter by Currey in 1873 Although the two genera were placed next to each other and it was recognized that they were closely related, the family did not assume its present form till Naumov (1939) excluded from it the genus *Cunninghamella*. Fitzpatrick (1930) included *Blakeslea*, *Choanephora* and *Cunninghamella* in this family, while Zycha (1935) enlarged it further to include *Rhopalomyces*, *Thamnocephalis* and *Sigmoideomyces* Hesseltine (1955) considered that the two genera *Blakeslea* and *Choanephora* are closely related to each other and distinct from others not only because they are short-lived in cultures but also on account of the presence of sporangia, sporangiola or conidia on fruiting stalks. Their zygospores are also unlike those of other members formerly included with them in the same family.

KEY TO THE GENERA

1 Conidia absent but sporangiola present .. .. . BLAKESLEA
2. Conidia present (absent in *C. persicaria*) but sporangiola never present. CHOANEPHORA

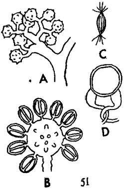
Genus BLAKESLEA Thaxter

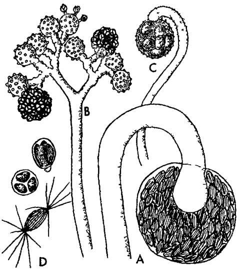
Bot Gaz. 58 : 353-366, 1914.

Conidia absent; sporangia of two types (Fig. 51), larger solitary ones possessing a columella and smaller ones termed sporangiola lacking a columella, occur in large numbers on the surface of large spherical sporangiferous heads, numerous intergrading variation between two types of sporangia quite common; larger sporangia extremely variable in size, sometimes not larger than sporangiola, columella often obsolete, sporangiferous heads sometimes solitary at the ends of erect unbranched sporangiophores, but usually in groups of ten or more and terminating branchlets of the subdichotomously branched end of the sporangiophore. Sporangiolum typically three-spored, rarely four-or six-spored, attached to the sporangiferous head by a small spherical vesicle, falling away at maturity and carrying the vesicle with it. Spores variable in size but generally similar in all types of sporangia, longitudinally striate, provided at each end

with a cluster of delicate, radiating appendages like those of sporangiospores of *Choanephora* Chlamydospores variable Zygospores, where known, formed between the tips of twining branches

Recently, this genus was merged with *Choanephora* (Currey, 1873) and its only known species was described as *C trispora* (Thaxter, 1903), but in the present treatment it is retained as a separate genus Hesseltine (1955) has retained the two genera According to him, the conidia are absent but sporangiola are present in *Blakeslea* while in *Choanephora* the conidia are present but sporangiola are lacking.





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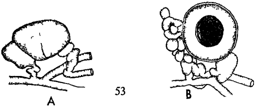


FIG 51 *Blakeslea* A, sporangiophore, B, sporangioles, C, sporangiospores, D, zygospore (After Zycha)

FIG 52 *Blakeslea trispora* Thaxter A, typical many-spored sporangium, B, typical sporangiola borne over globose heads at the apex, C, intermediate sporangium without columella, D, sporangiospores (After Naumov)

FIG 53 *Blakeslea trispora* Thaxter A, young zygospore, B, mature zygospore (After Couch)

Blakeslea trispora Thaxter

Bot. Gaz. 58 : 353-366, 1914

Syn. *Choanephora trispora* Sinha, *Proc. Indian Acad Sci* B. 11:167, 1940

C. dichotoma Gandrup, *Besoek Praefstat Meded*, 35· 1923.

Mycelium woolly, up to 0.5 cm high.

Cultures on potato dextorse agar develop honey-yellow colour, younger regions nearly white, slight odour present, growth similar to that of *Choanephora* Hyphae granular, 10 μ in diameter, showing light, twisted knots of mycelium at various places; sporangiophores short, apparently arising from the aerial mycelium, non-septate, 10 μ in diameter, readily collapsing, not branched, true sporangia large, spherical or slightly flattened, borne on straight or circinate sporangiophores, 25–72 μ in diameter, yellowish in early stages, becoming brown with age, sporangial wall rough at early stage, but becomes smooth at maturity, hyaline, breaking open at the tip to give two halves as in *Choanephora* Columella elongated, oval to pyriform, with a very small collar, varying in diameter, usually 20–25 μ, sporangioliferous sporangiophores branched above, branches ending in heads, 35–35 μ in diameter, these heads with sporangiola attached by means of small, spherical, vesicle-like sterigmata Sporangiola oval, 12–14 × 11–12 5 μ without columella, containing typically three, sometimes more, spores, wall hyaline. Sporangiophores from sporangia and sporangiola nearly equal, reddish brown, oval, striate, with appendages resembling bristles arising from a papilla at each end of the sporangiophore. Sporangiospores 8–14.5 × 4 3–8 μ. Chlamydospores present, 24 μ in diameter. Zygospores similar to those of *Choanephora*, globose, 40–60 μ in diameter on pincer-like suspensors (Figs 52, 53).

HABITAT: On *Colocasia antiquorum* (Sinha, 1940).
DISTRIBUTION. India (Lucknow), Canal Zone, Panama, U.S A.

Genus CHOANEPHORA Currey

J. Linn. Soc. Bot 13:333-578, 1873

Syn. *Cunninghamia* Currey, *loc. cit.* 13:334, 578, 1873.

Choanephorella Vuillemin, *Bull. Soc. mycol. Fr.* 20 26-33, 1904.

Blakeslea

Both sporangia and conidia present, and not infrequently arising from the same mycelium, sporangium terminal and usually pendent on the recurved end of an erect, unbranched sporangiophore provided with a definite columella which tends to be globose, and usually containing a large number of spores, though diminutive few-spored sporangia sometimes occur, sporangiophores usually ovoid to fusiform, but occasionally varying to unequilateral or triangular, not striate like conidia, provided with a cluster of very fine radiating appendages at both ends or also at the sides. Conidiophore on erect hypha, terminated in a capitate vesicle from which a few short branches emerge, these branches enlarging at their tips to form secondary vesicles usually without branching again. At maturity they are covered with short sterigmata bearing conidia, intercalary

chlamydospores with more or less thickened walls borne on the mycelium, zygospores observed in various species

Of the four to five species reported, three are found in India

KEY TO THE INDIAN SPECIES

1 Sporangia and conidia both present	
2 Secondary vesicles not persisting as funnel-shaped structures	*C. cucurbitarum*
2. Secondary vesicles persisting as funnel-shaped structures	
a. Vesicles rounded	*C infundibulifera*
b Vesicles abruptly truncate smaller than in (a)	*C simsoni*

Choanephora cucurbitarum (Berk et Revenel) Thaxter

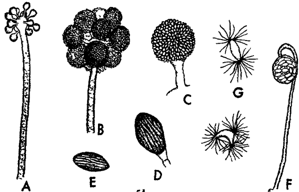
Rhodora 5 : 97-102, 1903

Syn. *Rhopalomyces cucurbitarum* Berk and Revenel, *Grevillea* 3-11, 1875
R elegans Corda var *cucurbitarum* Marchal, *Rev Mycol* 14 · 165, 1891
Cunninghamella manshurica Saito et Naganischi, *Rep centr S Mandsh Railway Co* 1·1914
Choanephora conjuncta Couch, in Poitras *J Elisha Mitchell Sci Soc* 41 .141,1925.

Colonies white to a dirty grayish-white, showing sporulation in concentric zones, later producing sterile mycelium, odour sweetish, resembling that of tomato leaves. Sporangiophores arising from surface hyphae, unbranched, gradually enlarging above, often bent or circinate below the sporangium, hyaline, becoming darkened above, with a maximum diameter of 30 μ Sporangia spherical to slightly flattended in the larger ones, at first white, later black, measuring up to 156 μ, more often 120 μ, containing from few to many sporangiospores, sporangial wall persistent, coloured, breaking from above to base to give two equal halves, columellae pyriform to globose, with a small collar, up to $120 \times 108\ \mu$, usually smaller; sporangiospores not striate, light-coloured, then brown, often granular, with hyaline hair-like bristles, 1 to 1 5 times as long as the sporangiospores, ovoid to ellipsoid to almost triangular, $18\text{-}27 \times 9 \times 12\ 6\ \mu$ averaging $22\ 2 \times 10\ 8\ \mu$; conidiophores up to 30 μ in diameter, ending in a primary vesicles from which secondary vesicles are produced on short stalks, secondary vesicles bearing conidia; conidia brown, ovoid, longitudinally striate, with a papilla at one end, lightly smaller than sporangiospores, $15\text{–}18 \times 9\text{–}11\ 5\ \mu$ (Fig 54), submerged mycelium with thickened granular regions, chlamydospores in some strains globose to oblong-ellipsoid, sometimes in chains; zygospores formed between equal suspensors, at maturity dark-brown, 50-90 μ, containing a large oil globule; zygospore walls smooth

HABITAT On *Capsicum* (Dastur, 1920), *Colocasia antiquorum* (Sinha, 1940), *Hibiscus esculentus* (Mitter and Tandon, 1937), *Zinnia* flowers (Raizada, (1956).

DISTRIBUTION: India, Malaya, and U S S R Fruits of *Cucurbita pepo* (Hasseltine, 1953), flowers and fruits of squash (Wolf, 1917) and pumpkins (Thaxter, 1903), cow-peas (Lefebvre and Weimer, 1939)



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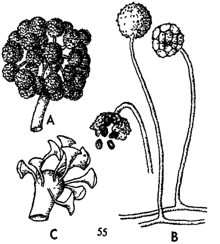

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FIG 54 *Choanephora cucurbitarum* Thaxter A, young conidiophore with spherical heads on which conidia are just beginning to form, B, same at later stage, the heads covered with conidia borne on short sperigenata, C, single head enlarged, D, single conidium, here shown to be infact a monospored sporangiolum, E, conidium of more usual aspect, the outer wall not evident, F, sporangium, G, sporangiospores (A–E after Thaxter, 1914 and F–G after Wolf, 1917).

FIF 55 *Choanephora infundibulifera* Cunningham A, conidiophore with spherical heads, covered with conidia borne on short sterigenata, B, sporangia at different stages, C, conidiophore after the discharge of conidia (After Naumov)

Choanephora infundibulifera (Currey) Cunningham

Trans Linn Soc 1 409-422, 1878

Syn *Choanephora cunninghamiana* Currey, *J Linn Bot* 13 333-334, 578, 1873

Cunninghamia infundibulifera Currey, *loc cit* 13 333-334, 578, 1873

Conidiophores up to 8 25 mm high, ending in a primary vesicle, thin with stalks bearing secondary vesicles with thick walls below and delicate walls above, thin-walled portion collapses and conidia fall to give pedicellate funnel-shaped structure, conidia at first white, then brown and finally deep purplish-black, 20×11 μ Sporangiophore generally shorter than conidiophores, curved at the apex, unbranched, sporangia spherical, deep brown, surface tuberculate with columellae, containing typically 7–8 spores, or sometimes even 18 spores, sporangial wall hyaline, rupturing vertically, sporangiophores brown, ovoid, without appendages (Fig 55), 13–20 $\times$ 9–13 μ Chlamydospores broadly fusiform, 30×16 μ Zygospores spherical, deep brown At maturity with a large oil droplet in the centre, 50–70 μ in diameter, wall smooth, suspensor tong-like

HABITAT On flowers of *Hibiscus rosa-sinensis* Cunningham, 1878, Mitter and Tandon, 1937)

DISTRIBUTION. Allahabad

Choanephora simsoni Cunningham

Ann. R bot Gard Calcutta, 6 163-174, 1895

Syn *Choanephora infundibulifera* (Currey) Cunningham, *Trans Linn Soc* 1·409 422, 1878.

Choanephora simsoni Cunningham, *Ann R bot Gard Calcutta* 6·163-174 Pl 8-9, 1895

Zycha (1935) treated *Choanephora simsoni* as a synonym of *C infundibulifera* while Naumov (1939) recognized it as a valid species The fungus was found parasitizing the leaves and petioles of *Ipomoea* and *Zinnia elegans* It is said to be smaller than *C infundibulifera* and to differ in having abruptly, truncate vesicles upon which the conidia are borne instead of on rounded vesicles as in *C infundibulifera* There are ten or more secondary vesicles bearing the conidia The conidia are fusiform and striate, measuring 15 $\times$ 8 μ The sporangiospores are fusiform and provided with a striate, brown epispore with radiate, thin bristles and are 16 8 $\times$ 8 9 μ The zygospores are deep brown to almost black and 57 μ in diameter

HABITAT· On flowers of *Zinnia elegans* (Cunningham, 1895, Mitter and Tandon, 1938)

DISTRIBUTION Calcutta, Pusa, Allahabad

APPENDIX

A number of Mucorales have so far not been reported from India. The generic characters and the representative sketches of such genera have been given here so that there may not be any difficulty in proper study or identification of such forms, if and when recorded from India

PIRELLA Bainier

Ann. Sci nat A 15.70-104, 1883

Characters are fundamentally similar to those of *Circinella*; but the sporangia are pyriform, columella constricted and spores elliptic (Fig 56).

Pirella circinans Bainier

Ann. Sci. nat. A. 15:70-104, 1883.

Sporangia 126×48 μ; wall very resistant not diffluent; columella with apophysis very much contracted in its middle; spores 6.3×2.1 μ.

DICRANOPHORA Schroter

Jahrb Schles. Ges Vaterl. Kutt 64· 184, 1886.

Sterile aerial mycelium present; sporangiophores terminate in a principal sporangium with numerous spores and columella, dichotomously branched sporangiophore with numerous sporangia of the second order possessing one to two reniform spores and a bi- or trilobed columella.

SPINELLUS van Tieghem

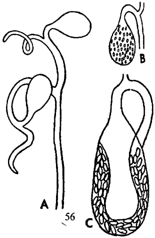
Ann Sci. nat. A 1·5-175, 1875.

Sterile aerial mycelium always present except in *S macrocarpus*; sporangiophores unbranched, single, swollen at the base, divided, enlarged at apophyses in their passage into the columella; sporangial wall thick and coloured, having in the dry state a metallic reflection, completely diffluent in water; spores pale slate, or brownish. Species homothallic, isogamous or anisogamous; obligate parasite on Basidiomycetes (Fig. 57).

PARASITELLA Bainier

Bull. Soc. mycol Fr. 19:153-172, 1903.

General apsect in every particular as that in *Mucor*, except that the zygophores are horned and that, in relation with the parasitic life, it forms the peculiar swellings and the 'pseudo-azygospores' (Fig. 58).



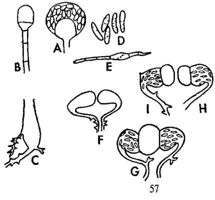


FIG 56 *Pirella* Bainier
FIG 57 *Spinellus fusiger* A, sporangium showing the insertion of the columella, B, columella (after dissemination of spores), C, base of the sporangiophore with projecting spines, D, spores, E, spore germination, F, conjugation of gametes, G, mature zygospore, suspensores with brown and clear spaces, H–I, two zygospores (After van Tieghem, 1875)

One heterothallic, isogamous species, *P simplex* Bainier is known as facultative parasite on several members of the Mucorales

PILAIRA van Tieghem

Ann Sci. nat. Bot. 1 5-175, 1875

Sporangiferous apparatus simple, mostly unbranched, losing its turgidity and sinking itself when completely mature Sporangia spherical or flattened in the young state, not projected Copulation branches adjacent curved like tongs (Fig 59)

COKEROMYCES Shanor

Mycologia 42:272, 1950.

Sporangioles produced abundantly on stalks over the surface of terminal capitate swellings of the sporangiophores; spores dark and not possessing radiating, delicate, cilium-like appendages, sporangia and conidia absent Zygospores produced between short, relatively straight, copulating branches as in *Mucor* or *Cunninghamella* and not between tips of twining branches as in *Blakeslea* or *Choanephora* (Fig 60)

CHAETOSTYLUM van Tieghem et le Monnier

Ann. Sci. nat A. 17-328, 1873.

It is similar to *Thamnidium* but branches of the second type are disposed in simple or composite whorls up to second or third order.

CHAETOCLADIUM Fresenius

Beit. zur. Mycol. Francfort 1850-1863.

Aerial mycelium creeping, consisting of stolons and sporangiferous apparatus;

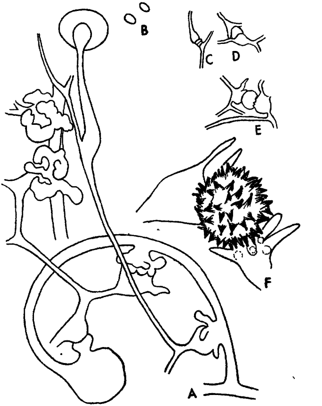
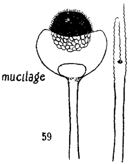


FIG 58 *Parasitella parasitica* A, fungus forming galls and a sporangium, B, spores, C–E, stages in the development of zygospore, F, mature zygospore with finger-like projections (A–B after Bainier, 1903, and C–F after Zycha)



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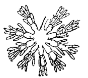

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FIG 59 *Pilaira cesatii* A ruptured sporangium
FIG 61 *Dispira americana* Head and sporiferous swellings

sporangia exclusively of second order, monospored, principal branches of the second order terminate in a long and sterile point, facultative parasites on the Mucorales (Fig 10)

DISPIRA van Tieghem

Ann. Sci. nat. R 1.5-175, 1875

Sporiferous apparatus single, perpendicular, with transverse divisions, many times branched in false dichotomy in the upper part, branches twisted in spiral, the ultimate one very frequently sterile, sporiferous swellings globular, with radiations, bicellular sterigmata; chain of spores short, rising in several from the upper part of every joint of the sterigmata; zygote devoid of swollen zygophores (Fig 61)

KICKXELLA

Bull. Soc. R. Bot. Belg. 1:155, 1862

Mycelium hyaline or light-coloured, sporangia absent, conidiophores simple or branched, always with sporocladia (special branches of the conidiophore which bear phialides on which single conidia are borne), arranged in a whorl at the end of a simple conidiophore, phialides simple, hyaline, ovoid to elongate-ellipsoid, conidia one-celled, sometimes pseudoseptate, hyaline to yellow, elongate-ellipsoid to needle-shaped, some with a capsule at one end, zygospores as in Piptocephalidaceae (Fig 62)

LINDERINA Raper et Fennell

Amer. J. Bot. 39:91, 1952.

Colony effuse, mucoroid, conidiophores arising primarily from submerged vegetative hyphae, separate, generally branched above, with terminal areas fertile and bearing few to many conidial heads acropetally, or infertile and capable of functioning as stolons, conidial heads consisting of sessile, non-septate ovoid to dome-like vesicles, or sporocladia, bearing crowded sterigmata, or phialides, on their upper surfaces Sterigmata unicellular, ellipsoid, with narrowed apices bearing single conidia (Fig 63)

MARTENSELLA Coemans

Bull Acad. R. Belg. 15·292, 183

Colonies effuse, forming a minutely and sparsely hirsute layer over the substratum pale-yellowish or cream-coloured, conidiophores simple, hyaline, 1–3-septate up to 200 μ long, 5.5–6.5 μ in diameter and bearing one or two, rarely three, sporocladia; the latter stipitate, septate, 25–36 μ long, inflated in the fertile portion where they are 7–10 μ in diameter, somewhat tapering to the bluntly rounded base and the sharply upturned sterile apex, stalk cell 9–12 5 $\times$ 4 5 μ; phialides 6–8 on the upper surface of the sporocladium, 5–6 $\times$ 3 5 μ; conidia elongate ellipsoid to subcylindrical, slightly tapering towards the base, rounded towards the apex, 105–13 $\times$3 5–4 5 μ (Fig 64)

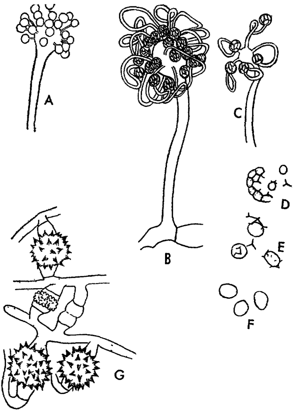
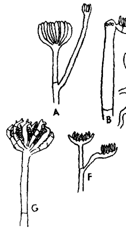
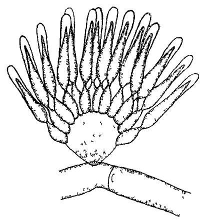


FIG 60. *Cokeromyces recurvatus* A–C, sporangiophores terminating by a definite swelling, D–E, thin bands of darkly pigmented substance attached to the sporangiole wall or adhering to the layer of sporee, F, spores, G, zygospore



62



63

FIG 62 *Kickxella alabastrina* A, young fructification, B, tip of a mature fructification with a single sporocladium attached showing mature spores attached on the upper surface, C, detached spores, D, germinating spores, E, different type of fructification obtained in culture F, chlamydospore in mycelium, G, mature fructification

FIG 63 *Linderina pennispora* Sporangium showing relationship of sporiferous elements

HAPLOSPORANGIUM Thaxter

Bot. Gaz 58.362, 1914

Axes of the first order mycelial, creeping, divided, moniliform, on the articulations of which arise short sporangiophores as lateral branches, which taper towards the apex and occasionally branch at right angle, monosporic or bisporic sporangium without columella developed on tips of branches (Fig 65)

ISSOPHORA Thaxter

Bot. Gaz 58 361, 1914

Sporangiferous apparatus composed of robust axes of the first order, of indefinite growth, the short axes of the second order, formed continually towards the summit of the first, are the proper sporangiophores (Fig 66)

MYCOTYPHA Fenner

Mycologia 24 187, 1932

Thallus much-branched, diameter of the mycelium variable, sterigmata appearing as swellings on the capitallum from which conidia bud and enlarge until they entirely cover the hollow cylindrical head, capitella variable in length 20 μ to over 500 μ with

the spores removed; conidiophores frequently bearing lateral branches, several times as long as the cylindrical heads, non-septate in a fresh culture, numerous septa formed at intervals of 8 to 10 μ or even less usually 3 to 4 days after germination This septation is characteristic of *Thamnocephalis* and its near relatives, conidiophores at first hyaline but become yellowish with age; conidia ovoid to spherical, hyaline to pale bluish-green; caducous at maturity, leaving the hollow cylindrical head exposed; under low power the naked capitellum appears to be marked with many aerolations of orifices but proper

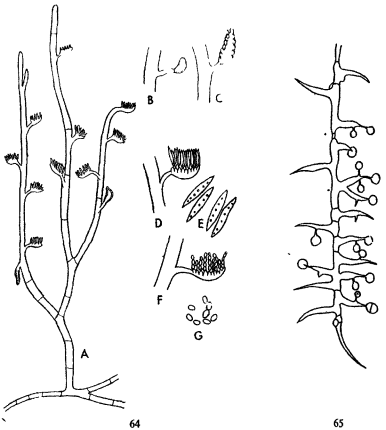


FIG 64. *Martensella pectinata* Coem. A, portion of the main plant, B, young sporophore; C, sporophore with developing spores, D, sporophore with mature spores; E, fusiform spores; F; sporophore with conidia; G, conidia (After Coemans, 1863)

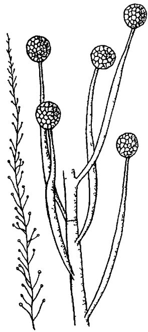
FIG 65. *Haplosporangium bisporale* (After Thaxter. 1914)

focussing after the spores have fallen off reveals numerous protuberances bearing scars where the sterigmata were attached. Sterigmata generally adhere to the conidia as small, hyaline, beak-like appendages after the conidia have dropped from the head, spores 2 to 4 μ (average 2.5 μ) in diameter (Fig. 67).

THAMNOCEPHALIS Blakeslee

Bot. Gaz. 40.165, 1906

Conidioferous apparatus clearly differentiated, distinct from the mycelium, verti-



66

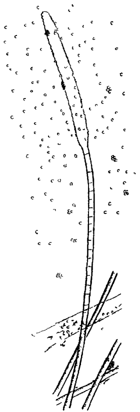


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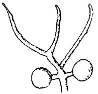
FIG. 66. *Dissophora decumbens*. A sporangiophore with sporangia.
FIG. 67. *Mycotypha microspora*. Septation of the conidiophore which occurs after maturity is reached.



68

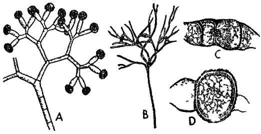


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FIG 68 *Thamnocephalis quadrupedata* Two young swellings, that have not yet developed the conidia.
FIG 69 *Sporodinia grandis* Link A, sporangiophores and sporangia, B, zygophore showing conjugating gametangia, C, gametangia suspensors, D, mature zygospore (A, after Lendner, 1908, B, after De Bary, 1894, C,D, after Keene, 1914)

cal, very frequently the base of the rhizoids spread out as star, and the apical portions dichotomously branched; branches prostrate, terminating in a swollen conidiophore at the top from which the branches continue after their division for forming the sterile branches (Fig. 68).

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Appendix II

Family Mucoraceae

Absidia

Absidia capillata van Tieghem
(M.D. Mehrotra, 1964, source unknown)
A. clavata Mehrotra & Krishnanand
(Mehrotra and Krishnanand, 1967, from cowdung, Allahabad)
A. cylindrospora Hagem
(Saksena, Sarbhoy and Krishnanand, 1967, from soil of U.P.)
A. dubia Bainier
(M.D. Mehrotra, 1964, source unknown)
A. orchidis (Vuill.) Hagem
(Saksena and Sarbhoy, 1962, from soil of Allahabad)
A. ornata Sarbhoy
(Sarbhoy, 1965b, from bird excreta, Vindhyachal)
A. ramosa (Lindt) Lendner
(Saksena and Sarbhoy, 1963, from soil of U P , Saksena, Sarbhoy and Krishnanand, 1967, from soil of U.P.)
A. reflexa van Tieghem
(Saksena, Krishnanand and Sarbhoy, 1967, from soil of U.P.)

Circinella

Circinella mucoroides Saito
(Sarbhoy, 1965, from soil of Lucknow, Saksena, Krishnanand and Sarbhoy, 1967, from soil of U.P)

C. rigida Smith
(Sarbhoy, 1965, from soil of Jhansi; Saksena, Krishnanand and Sarbhoy, 1967, from soil of U.P.)
C. umbellata van Tieghem & Le Monnier
(Rai and Mukerji, 1961, from soil of Lucknow)

Gilbertella

Gilbertella persicaria var. *indica* Mehrotra (B.S.) & Mehrotra (M.D.)
(B.S. Mehrotra and M.D Mehrotra, 1964 b, from decomposing flowers of *Thevetia neriifolia*; Mehrotra (M D.), 1964, from rotten fruit of tomato)

Gongronella

Gongronella butleri var. *proliferans* Misra
(Misra, 1965, from soil of Varanasi)

Rhizopus

Rhizopus chinensis Saito
(Mukerji, 1969, from soil of Delhi)
Rhizopus cohnii Berlese & de Toni
(Saksena, Sarbhoy and Krishnanand, 1967, from soil of U.P.)
R. homothallicus Hesseltine & Ellis
(Rai and Tewari, 1962, from soil of Lucknow)
R. sexualis (Smith) Callen
(Baijal, 1963, from soil of Allahabad)

Phycomyces

Phycomyces nitens Agardh
(Saksena and Sarbhoy, 1962, from soil of Allahabad; Varma and Khan, 1965, from *Sorghum* seeds)

Mucor

M. abundans Povah
(Sarbhoy, 1965, from soil of Allahabad)
M. alternans van Tieghem
(Mehrotra and Krishnanand, 1967, from soil of Allahabad)
M. bacilliformis Hesseltine
(Rai and Mukerji, 1961, from soil of Lucknow)
M. bainieri Mehrotra & Baijal
(Benjamin and Mehrotra, 1963, from soil of Ranikhet)
M. brunneus Naumov
(Mehrotra, 1964, source unknown)
M. corticolus Hagem
(Mehrotra and Krishnanand, 1967, from soil of Allahabad)
M. genevensis Lendner
(Rai and Mukerji, 1961, from soil of Lucknow; Mehrotra (B.R.), Baijal and Mehrotra (B.S.), 1966, from soil of Manda)
M. globosus Fischer
(Sarbhoy, 1965c, from soil of Ranikhet; Saksena, Krishnanand and Sarbhoy, 1967, from soil of Ranikhet)
M. griseo-lilacinus Povah
(Mehrotra and Krishnanand, 1967, from soil of Allahabad)
M. griseo-ochraceus var. *minuta* Baijal & Mehrotra
(Baijal and Mehrotra, 1966, from soil of Shillong)
M. heterosporus Fischer
(Baijal and Mehrotra, 1966, from soil of Shillong)
M. indicus Lendner
(Ajrekar and Rajulu, 1931, from soil of Bombay)
M. jansseni Lendner
(Agnihothrudu, 1957, from rhizosphere of pigeon pea, Madras; Saksena and Sarbhoy, 1963, from soil of U.P.; Saksena, Krishnanand

and Sarbhoy, 1967, from soil of U P, Mehrotra, Baijal and Mehrotra, 1966, from soil of Panchmarhi rotten papaya fruit and almond)

M lamprosporus Lendner
(Baijal and Mehrotra, 1966, from soil of Shillong)

M lausannensis Lendner
(Mehrotra and Sarbhoy, 1960, from soil of Allahabad, Mehrotra, Baijal and Mehrotra, 1966, from soil of Gorakhpur, Sarbhoy, 1965, from dog excreta; Saksena, Krishnanand and Sarbhoy, 1968, from soil of U P)

M. luteus var. *indica* Baijal & Mehrotra
(Baijal and Mehrotra, 1966, from rotten fruit of *Ficus*)

M. microsporus **Namyslowski**
(Mehrotra and Krishnanand, 1967, from soil of Gyanpur)

M. mousanensis **Baijal & Mehrotra**
(Baijal and Mehrotra, 1966, from mouse dung)

M. oblongisporus **Naumov**
(Roy and Dwivedi, 1962, from soil of Varanasi)

M. petrinsularis **Naumov**
(Baijal and Mehrotra, 1966, from soil of Shillong)

M. pusillus **Lindt**
(Saksena and Sarbhoy, 1963, from soil of Ranikhet, Mehrotra, Baijal and Mehrotra, 1966; Saksena, Krishnanand and Sarbhoy, 1968, from soil of U.P.)

M. ramificus **Mehrotra & Krishnanand**
(Mehrotra and Krishnanand, 1967, from soil of Ghazipur)

M. ramosissimus **Samutsewitch**
(Sarbhoy, 1965, from soil of Allahabad)

M. recurvus **Butler**
(Baijal and Mehrotra, 1966, from soil of Allahabad)

M. recurvus **var. *indica* Baijal & Mehrotra**
(Baijal and Mehrotra, 1966, from soil of Allahabad)

M. subtilissimus **Oudemans**
(Mehrotra and Krishnanand, 1967, from soil of Vindhyachal)

M. suhagiensis **Mehrotra**
(M.D. Mehrotra, 1964, from soil of Suhagi)

M. peacockensis **Mehrotra & Krishnanand**
(Mehrotra and Krishnanand, 1967, from soil of Ghazipur)

M. variabilis **Sarbhoy**
(Sarbhoy, 1965a, from soil)

M. varians **Povah**
(Baijal and Mehrotra, 1966, from soil of Allahabad)

M. zychae **Baijal & Mehrotra**
(Baijal and Mehrotra, 1966, from soil of Allahabad)

Zygorhynchus

Zygorhynchus heterogamus (Vuill.) Vuill.
(Rai and Mukerji, 1961, from soil of Lucknow; Saksena and Sarbhoy, 1963, from soil of U.P.)

Family Thamnidiaceae

Chaetocladium

Chaetocladium brefeldii van Tieghem
(Singh, 1968, from soil of Allahabad)
Chaetocladium hesseltinii Mehrotra & Sarbhoy
(Mehrotra and Sarbhoy, 1960a, from soil of Allahabad; Mukerji, 1969, from soil of Delhi)

Helicostylum

Helicostylum cordense Mehrotra & Mehrotra
(B.S. Mehrotra and B.R. Mehrotra, 1963, from soil of Manda)
H. lucknowense Rai, Tewari & Mukerji
(Rai, Tewari and Mukerji, 1960, from soil)

Family Piptocephalidaceae

Piptocephalis

Piptocephalis brijmohanii Mukerji
(Mukerji, 1968, from soil of Delhi)
P. indica Mehrotra & Baijal
(Mehrotra and Baijal, 1964, from rabbit dung, Lucknow)
P. tieghemiana Matruchot (as *Piptocephalis* sp.)
(Mehrotra and Baijal, 1964, from dung of squirrel; Mukerji, 1968, from soil of Delhi)
P. curvata Baijal & Mehrotra
(Baijal and Mehrotra, 1968, from soil of Shillong)

Syncephalis

Syncephalis bispora Raciborski
(Mehrotra and Prasad, 1966, from soil of Allahabad)
S. depressa van Tieghem & Le Monnier
(Mehrotra and Prasad, 1964, from dung of mule)
S. drechsleri Mehrotra & Prasad
(Mehrotra and Prasad, 1966, from soil of Jaunpur)
S. furcata van Tieghem
(Mehrotra and Prasad, 1966, from soil of Jaunpur)
S. plumigaleata Indoh
(Mehrotra and Prasad, 1967, from soil of Allahabad)

S pycnospermum var *subglobosa* Mehrotra & Prasad
(Mehrotra and Prasad, 1966, from soil of Allahabad)
S. tenuis Thaxter
(Mehrotra and Prasad, 1966 from soil of Allahabad)
S trispora Mehrotra & Prasad
(Mehrotra and Prasad, 1967, from soil of Allahabad)

Family Dimargaritaceae

Dimargaris

Dimargaris oblongispora Mehrotra & Baijal
(B.S. Mehrotra and Baijal, 1963, from dung, Allahabad)
D. simplex Mehrotra & Baijal
(B.S Mehrotra and Baijal, 1964a, from soil of Lucknow)
D. verticillata Benjamin var *xerosporica* Mehrotra & Baijal
(B.S Mehrotra and Baijal, 1964, from dung of snail)

Family Kickxellaceae

Coemansia

Coemansia interrupta Lendner
(Mehrotra, Singh and Krishnanand, 1968, from forest soil of Ranchi)
Coemansia spiralis Eidam
(Mehrotra, Singh and Krishnanand, from soil, Allahabad)
Coemansia reversa van Tieghem & Le Monnier
(Agnihothrudu, 1957, from rhizosphere soil, Madras, Mukerji, 1968a, from rabbit dung)
Coemansia ceylonensis Linder
(Prasad, 1966, from soil of Allahabad)
Coemansia erecta Bainier
(Mehrotra, Singh and Krishnanand 1968, from mouse dung)

Linderina

Linderina pennispora Raper & Fennell
(Baijal, 1963a, from soil of Allahabad)

Family Mortierellaceae

Mortierella

Mortierella alpina Peyronel
(B S Mehrotra and B R. Mehrotra, 1964, from soil of Allahabad)
M. ambigua Mehrotra (B.S.)
(B.S. Mehrotra, Baijal and B R Mehrotra, 1963, from soil of Allahabad; Sarbhoy, 1965, from soil of Almora and Ranikhet)

M. hygrophila Linnemann

(B S. Mehrotra and B R. Mehrotra, 1964, from soil of Rishikesh)

M. mehrotraensis Baijal

(Baijal, 1969, from excreta of snail)

M. polycephala van Tieghem

(B.S. Mehrotra and Baijal, 1963a, from soil of Rishikesh)

M. rishikesha Mehrotra & Mehrotra

(B.S. Mehrotra and B.R. Mehrotra, 1964, from soil of Rishikesh)

M. sterilis B.S. Mehrotra & B R. Mehrotra

(B.S. Mehrotra and B.R. Mehrotra, 1964, from soil of Allahabad, and Rewa)

M. spinosa Linnemann

(Baijal, 1969, from soil of Allahabad)

M. vesiculosa B.S. Mehrotra, Baijal & B.R. Mehrotra

(B S. Mehrotra, Baijal and B.R. Mehrotra, 1963, from soil of Rishikesh)

M. oligospora Bjorling

(B.S. Mehrotra, B.R. Mehrotra and Baijal, 1964, from soil of Allahabad, Rewa and Rishikesh)

M. oligospora Bjorling var. *indica* B.S. Mehrotra & Baijal

(B.S. Mehrotra, B.R. Mehrotra and Baijal, 1964, from soil of Hoshangabad)

M. striospora Deshpande & Mantri

(Deshpande and Mantri, 1965, from bean pod, Aurangabad)

M. wolfii Mehrotra & Baijal

(B.S. Mehrotra and Baijal, 1963a, from soil of Jobner)

Family Choanephoraceae

Blakeslea

Blakeslea monospora Mehrotra & Baijal

(Mehrotra and Baijal, 1968, from soil of Vindhyachal)

Blakeslea tandonii Mehrotra

(M.D. Mehrotra, 1964a, from soil of Nainital)

Choanephora

Choanephora conjuncta Couch

(B.S. Mehrotra and M.D. Mehrotra, 1964, from soil of Allahabad; Mukerji, 1966, from soil of Lucknow)

Choanephora circinans (Naganishi & Kawakami) Hesseltine & Benjamin var. *prolifera* Mehrotra & Mehrotra

(B.S. Mehrotra and M.D. Mehrotra, 1964, from soil of Amarkantak, Suhagi, Mirzapur and Calcutta)

Choanephora circinans var. *indicus* R.Y. Roy & S Gujarati

(R.Y. Roy and S. Gujarati, 1964-65, from decaying grass roots)

Choanephora heterospora B.S. Mehrotra & M.D. Mehrotra

(B S. Mehrotra and M.D Mehrotra, 1961, from a dead insect)

Family Cunninghamellaceae

Cunninghamella

Cunninghamella bainieri Naumov
(Saksena, Krishnanand and Sarbhoy, 1967, from soil of Chaubatia)
C. blakesleeana Lendner
(Misra, 1966, from forest soil of Gorakhpur)
C brunnea Rai, Agarwal & Tewari
(Rai, Agarwal and Tewari, 1968, from soil of Lucknow)
C. intermedia Deshpande & Mantri
(Deshpande and Mantri, 1966, from rotting filter paper, Aurangabad)
Cunninghamella vesiculosa Misra
(Misra, 1963, from forest soil of Gorakhpur)

Mycotypha

Mycotypha microspora Fenner
(Ghosh and Pathak, 1962, from soil)

Thamnocephalis

Thamnocephalis ovalispora B S. Mehrotra & B.R. Mehrotra
(B S. Mehrotra and B.R Mehrotra, 1963, from dung of bat)

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ERRATA

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7	4	1887	1987
10	40	spores	sporangiophores
17	37	*Blakeslea trispora*	*Blackeslea trispora*
18	3	L—arabinose	L—arainose
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20	37	by this organism	by organism
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47	18	Rabenhorst's	Rabenhort's
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50	6	sporangiospores	sprangiospores
51	17	opposite	oppsoite
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53	18	Kryptogamenfl	Kryptogamienfl
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60	10	75-120	751-20
60	11	80-90	809-0
60	22	*M. prainii*	*M praini*
60	33	*M lausannensis*	*M lansannensis*

Page	Line	Read	For
61	36	Roger	Rogar
62	1	Hagem	Oagem
62	21	*Mucor racemosus* Fres.	Mucor racemosus
62	29	ovoid	avoid
63	15	*Mucor prainii*	*Mucor praini*
63	15	Chodat	Chodate
63	15	Nechitsch	Nechitch
66	10	*Mucor luteus* Linnemann	*Mucor luteus* Gleditsch
67	28	*Mucor mucedo* Linne ex Fres.	*Mucor mucedo* (Linne) ex Fres.
67	30	Povah	Pavah
67	30	1897	1997
67	32	Schostakoritsch	Schostakouritsch
70	19	of Mucoraceae	of as Mucoraci
72	22	swelling	sewlling
75	1	on	one
75	9	cylindrical	cyclindrical
75	11	Ginai	Ginali
77	15	*Helicostylum piriforme*	*Helicostylum pyriformi*
78	15	*Piptocephalis freseniana*	*Piptocephalis fresiniana*
81	1	*Syncephalastrum racemosum* (Cohn) Schroet	*Syncephalastrum racemosum* (Cohn)
87	9	(1862)	(1962.)
87	20	Piptocephalidaceae	Phitocephalidaceae
90	20	sporangiospores	sporangiophores
90	21	sporangiospores	sporangiophores
91	1	Linnemann	Einnemann
92	11	intercalary	intercallary
98	19	Sporangiospores	Sporangiophores
98	35	sporangiospores	sporangiophores
100	3	sterigmata	sperigenata
100	8	sterigmata	sterigenata
101	11	sporangiospores	sporangiophores
101	21	Cunningham	Canningham
103	8	PILARIA	PILAIRA
105	12	KICKXELLA Coemans	KICKXELLA
106	10	10.5-13	105-13
106	13	spores	sporee
107	3	F	E
107	3	E	F
107	12	DISSOPHORA	ISSOPHORA
107	20	capitellum	capitallum
114	9	MEHROTRA, B.S.	MEHROTRA, B.A.
114	22	Cles	Cless
117	2 (col. 1)	*blakesleeana*	*blakesleana*
117	12 (col. 1)	*lichtheimi*	*lichthemii*
118	7 (col. 2)	*albo-ater*	*Albo-altar*
118	11 (col. 2)	*bainieri*	*baineri*
118	34 (col. 1)	*Helicostylum*	*Hellicostylum*
118	35 (col. 1)	*piriforme*	*pyriformi*
118	48 (col. 2)	*lausannensis*	*lansannensis*
118	60 (col. 2)	*prainii*	*praini*
119	22 (col 1)	*simplex*	*symplex*